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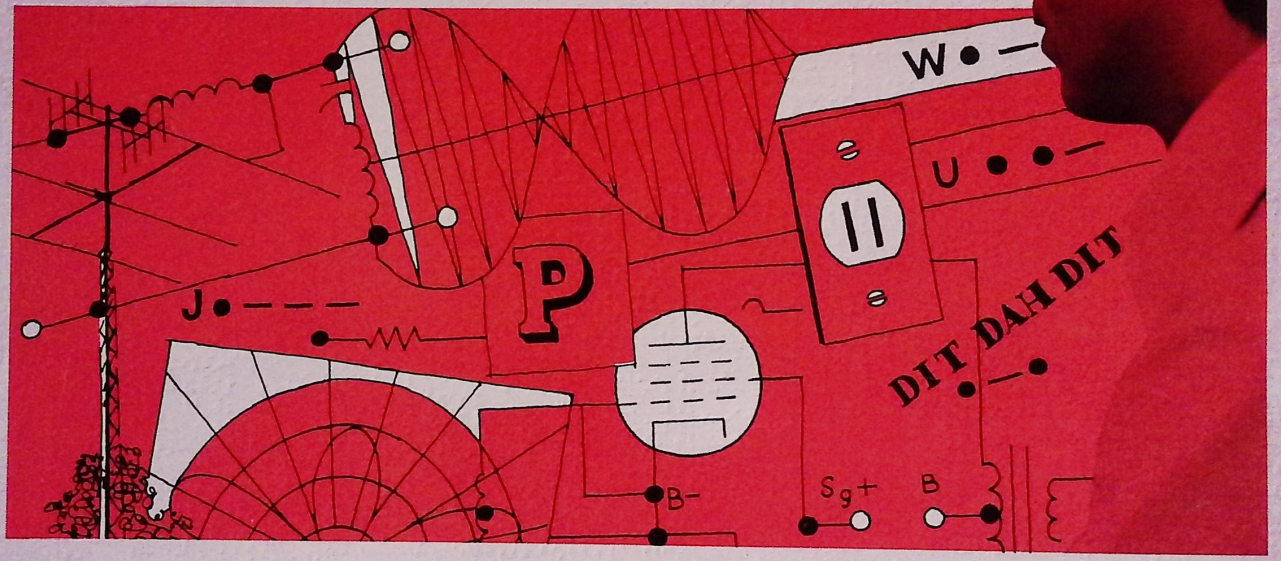


A PROGRAMMED COURSE TO TAKE YOU FROM CB TO HAM RADIO

THEORY
TEST QUESTIONS –
LEARN CODE QUICKLY
AND EASILY

EDITED BY
RADIO SHACK'S
STAFF OF HAM
RADIO OPERATORS

INTRODUCTION

CQ WORLD! CQ WORLD! CQ WORLD! . . . This is W----; W----; W----; . . . Over!

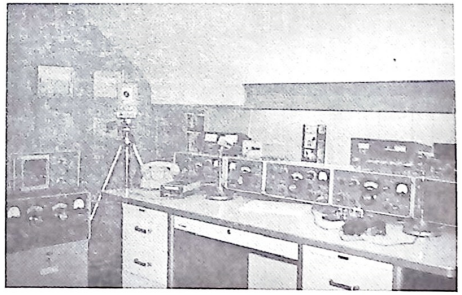
If you've read this far, you may have already started on the road toward making that "call" a reality for yourself!

Yes! Amateur radio is fascinating! You can talk to the world from your "hamshack". You will meet new friends in Radio Clubs and in "Amateur Radio Nets". You will "handle traffic" and relay messages via the magic of radio. You may sometime be involved in saving lives by providing emergency communications during a natural disaster, or after an accident. In addition, it is almost a "sure-fire" thing that once you have your Ham ticket, you'll frequently enjoy the art of "rag-chewing" (just talking with other amateur operators from all over, on the air). Perhaps you'll be the type who enjoys the aspect of experimentation and building your own electronic equipment. Whatever "your thing" . . . you'll find that Amateur Radio is truly fun! fascinating! and a fantastic hobby.

In this PROGRAMMED STYLE book, you will find that learning is easy! We don't want to imply that learning comes without effort . . . but we know that you'll find that learning in "digestible bits" and getting virtually "instant feedback" as to whether you are grasping the key ideas, will be very helpful to your learning process.

The basic philosophy of the book is to have you UNDERSTAND CONCEPTS RATHER THAN MEMORIZE A GROCERY LIST OF FACTS! Wherever it is possible to have you learn to understand key principles and concepts, rather than have you simply memorize a fact . . . we will do it!

Before we show you "how to use" the book . . . take a look at the pictures below of just a few of the many available Amateur Radio activities that you will be able to participate in after you've studied this book. We hope these will inspire you to jump into the learning experiences of this book . . . get your Amateur Radio license . . . and truly travel the road "from 5 watts . . . to . . . 1000 watts!



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ABOUT THE BOOK

The 3-R's of learning are: "Read, Recite, Review". In this book we've attempted to incorporate somewhat the same idea . . . but in this case we've altered it into a "studying and performing" and "learning and doing" format.

The first thing you'll notice about the presentation in this book is that the material is broken into "small digestible bits." You are given a "frame" (single step) of information in column 1 . . . then asked to use this information, or to recall it in a practical way by means of a "checkpoint" in column 3. You can immediately check your response by using a movable "PROGRAMMED PROGRESS COVER". This is a little cover device that you slide down the printed columns of the book as you progress through the learning material. For illustrated directions on how to use this device, see page 4. The beauty of the "instant feedback" technique is that if you did not understand a particular frame of material, you can immediately "recycle" yourself an appropriate amount backward in the material to assure that you do get the understanding needed before proceeding. This eliminates finding out "way downstream" that you need to restudy huge segments of material because you missed out somewhere . . . and didn't know it. Incidentally, Column 2 is an additional information column in which pictures, charts, diagrams, etc. appear for clarification.

Another very interesting feature of the book is that the practice exercises and problems can be used for studying in either of two ways. If no equipment is available . . . you can perform the exercises in a "paper and pencil" fashion; however, if you have basic electronic parts and equipment . . . or wish to procure some . . . many of the exercises can be actual laboratory "DOING PROJECTS".

Let's mention here that the equipment needed is minimal, and can be acquired at nominal cost from your neighborhood Radio Shack. For most of the projects, all that is needed is a variable voltage power supply, a few loose parts (like resistors, etc.) and a Multimeter (sometimes referred to as a VOM) for measuring electrical parameters.

O.K. Take a look at the page that shows you how to use the "PROGRAMMED PROGRESS COVER" . . . then start the fun of using it. We wish you good success as you commence this "self-paced, individualized instruction" learning procedure. May you quickly be able to move "from 5 watts . . . to 1000 watts"!

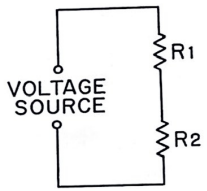
USING THE "PROGRAMMED PROGRESS COVER"

Below is a sample of the "three-column" approach used in this book. An example is given of how the "cover" is used to "hide the answer" for a checkpoint until you've had time to give your answer . . . then, of course, you would simply move the cover downward to reveal the correct answer . . . and to check yourself. To make a Programmed Progress Cover, just cut a thin piece of cardboard, about 11" wide by 2—4" high; then use it as illustrated.

INFORMATION

Ohm's Law states that electrical current is DIRECTLY related to voltage. This means that if the applied voltage to a given electrical circuit is doubled . . . then, the circuit current will double.

REFERENCE



CHECKPOINTS

CHECKPOINT:

If the voltage input to the circuit shown in column 2 were tripled . . . what would happen to the circuit current?

"PROGRAMMED PROGRESS COVER"

ANSWERS:

It would triple!
Note: "increase" would also be a good answer, but "triple" is a more precise answer.

MOVE COVER DOWN
AS YOU PROGRESS!

OK, we've introduced you to our book.

Now let's give you some suggestions and pointers.

The purpose of this book is to help would-be Hams to get their license (whether you're) a CBer or otherwise)—and have fun doing it.

The book is presented in such a form that you can use it in a "home study" situation—or in a class room . . . with large or small groups . . . all can use it and gain a good understanding of Ham radio.

The book has deliberately been organized so there is lots of working space for calculations and notes—use the blank spaces for your figuring and doodling—it's meant to be a "lab/workbook", so use it that way.

We've divided the book into 4 chapters:

- Learning the Code
- Novice License
- Technician License
- General License

Let's talk a little about Chapter 1—Learning the Code.

Chapter 1 has been included in the book particularly for those who do not have access to a "sound" method of learning code. If you have a "sound" method available (such as Radio Shack's tapes or records, a receiver capable of receiving code practice sessions directly off-the-air, etc.), we urge you to learn the code this way. If you can't get to one of these—use Chapter 1 just as it stands . . . "it'll work, if you work it!"

In either case (by "sound" or using Chapter 1 as is), you should go ahead and start working on Chapter 2 . . . at the same time you work with the code.

Read the paragraphs in Chapter 1 titled "A New Language", "Simulating the Sounds of Code" and "The Mechanics of Space and Timing". Then, proceed to study the code as suitable for your situation . . . but also begin your theory study in Chapter 2 and on.

Good luck in your studies!

By the way, I'd personally be interested in your comments and ideas about this book . . . if it's well received, we may try another in this same style.

Russell L. Meade

Chapter 1

LEARNING THE INTERNATIONAL MORSE CODE

A NEW LANGUAGE

Radiotelegraph code is a different language . . . but it's a universal language! Fortunately, code is not as difficult to learn as other languages. Thank goodness, there's no parts of speech, idioms, or conjugation of verbs to worry about. It really boils down to simply learning some "sound patterns."

Because it is necessary to learn to identify "sound patterns" . . . THE ONLY WAY TO PROPERLY LEARN CODE IS BY SOUND . . . AND BY SOUND ONLY! DON'T MEMORIZE WRITTEN CODE CHARTS!

For this reason we highly recommend that you practice the sounds AT EVERY OPPORTUNITY by . . .

INFORMATION

SIMULATING THE SOUNDS OF CODE

Before we begin to show you these "patterns in sound" mentioned earlier—let's look at a simple method of simulating code-like sounds.

Incidentally, we want to emphasize that you should learn sound patterns . . . that is, complete character sounds, rather than individual dots or dashes. In fact it is very interesting to note that as one becomes more and more proficient in code, he not only hears complete characters (letters, numbers or punctuation marks), but, whole-word sound patterns. Really expert code men can hear patterns far in excess of single words. This last level of proficiency is really not needed for passing Amateur License exams, but many hams do like code so much that they achieve this by on-the-air experience.

For the time being, let's learn how we simulate dots and dashes.

A series of dots can be simulated by voice by a rapid repetition of the syllable **"di"** . . . pronounced like the first part of the word **di**d. This series of "**di**'s" should all be run together in a staccato string. Try saying **"di-di-di-dit."** Notice that the last syllable has a "t" attached, denoting the end of the series. Try a string of 10, and keep trying until you can say them smoothly run together with a staccato, even repetition of each syllable. Don't get discouraged, you'll have a "trained tongue" with just a little practice.

Try some more "**di**'s" — **"di-di-di-di-di-di-dit".** Don't worry about sounding silly—this is one of the best ways to get used to the "sound of code". Practice some more—**OUT LOUD!**

O.K.—to simulate a dash, we say the sound **"dah"**, pronounced like half of the word "da da", used by babies to win the hearts of their fathers.

Try a string of five, or so, of these to get the feel. **"Dah-dah-dah-dah-dah."** Each of these **"dah"** syllables should be about 3 times the duration of the staccato "dits" we practiced earlier.

While we're on the subject; let's talk for a minute about . . . . .

THE MECHANICS OF SPACE AND TIMING

The time relationships of dits and dahs, and the spacing used between "elements" (a **dit** or a **dah**), characters and words is really quite simple.

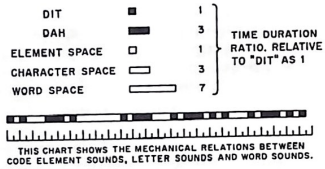
Notice in the illustration that the **"dit"** is considered our standard reference for time. This means that the dit = 1 unit of time. Everything else can be related to this. For example:

the **dah** = 3 units of time;
the time between **dits** and **dahs** in a single character (letter, number or punctuation mark) = 1 unit of time;
the time between characters = 3 units of time (same as the **dah**);
and the time between words = 7 units (or 7 dits)

All right! Let's try combining the **dit** and **dah** sounds to form some practice characters.

A good one to try here might be the character "R" . . . sounded as: **"di-dah-dit"** (accent the **dah**). The rhythm should be similar to the rhythm you would use to say the phrase "I'm learning code!" . . . with the word "learning" accented. Try this a few times to get the feel of the rhythm . . . then practice the letter R (**di-dah-dit**) until it feels natural.

Here's the first group of random characters we'd like you to practice. Practice each character until you have it . . . then, try combining them to form groups of letters. Remember to allow 3 units of time between each letter (character) when doing a series of two or more letters in a group. We want to recommend here that you practice "groups of 5" letters in any given group. You will see the reason for this later.



THIS CHART SHOWS THE MECHANICAL RELATIONS BETWEEN CODE ELEMENT SOUNDS, LETTER SOUNDS AND WORD SOUNDS.

FIRST GROUP OF RANDOM CHARACTERS

T = **dah**
H = **di-di-di-dit**
E = **dit**
R = **di-dah-dit**
O = **dah-dah-dah**

Note: When initially learning any new letter or character, say the sound . . . then the letter—**out loud**. Repeat this over and over until you feel you know the sound for that letter. Then, move on to another letter and do the same thing . . . then, a third, and so on. After you feel you know the sound for each of the letters in the "new" group of letters you're learning, then begin to mix them up. Here's an exercise to help you get the idea of how to learn new letters . . . but you can expand on this idea as you need to.

INFORMATION

To help you get started, here are some code exercises for you. Try to accent the dahs . . . allow 3 units of time between characters . . . and 7 units of time between "groups".

If you can get a friend who can "send" these letters and groups to you; either by the ***di-dah*** *method, or with a code practice oscillator,* ***after*** *you have thoroughly learned the letters by "didahing" to yourself, you will find it quite helpful as receiving practice.*

For most people, receiving code takes much more initial practice than sending code. We'll teach you to send a little later. Right now, concentrate on learning to hear the sound patterns for each character . . . so no matter where it "appears" in a group of code characters . . . you automatically say . . . or write down the correct letter when you hear its sound pattern.

REFERENCE & DATA

Initial Exercise: (sound it . . . then say the letter—**out loud.**)

dah T; **dah** T; **dah** T; **dah** T; **dah** T;
dah T; **dah** T; **dah** T; **dah** T; **dah** T.

di-di-di-dit H; **di-di-di-dit** H;
di-di-di-dit H; **di-di-di-dit** H;
di-di-di-dit H; **di-di-di-dit** H;
di-di-di-dit H; **di-di-di-dit** H;
di-di-di-dit H; **di-di-di-dit** H.

dit E; **dit** E; **dit** E; **dit** E; **dit** E;
dit E; **dit** E; **dit** E; **dit** E; **dit** E.

di-dah-dit R; **di-dah-dit** R;
di-dah-dit R; **di-dah-dit** R;
di-dah-dit R; **di-dah-dit** R;
di-dah-dit R; **di-dah-dit** R;
di-dah-dit R; **di-dah-dit** R.

dah-dah-dah O; **dah-dah-dah** O;
dah-dah-dah O; **dah-dah-dah** O;
dah-dah-dah O; **dah-dah-dah** O;
dah-dah-dah O; **dah-dah-dah** O;
dah-dah-dah O; **dah-dah-dah** O.

Second Exercise: (say the sound . . . then the letter, etc.)

dah T; **dah** T; **di-dah-dit** R;
di-dah-dit R; **dit** E; **dit** E;
di-dah-dit R; **dah** T; **di-dah-dit** R;
dit E; **dah** T; **dit** E; **dit** E;
dah-dah-dah O; **dah-dah-dah** O;
di-di-di-dit H; **di-di-di-dit** H;
dah-dah-dah O; **di-di-di-dit** H;
dah T; **di-di-di-dit** H; **dah-dah-dah** O;
di-dah-dit R; **di-dah-dit** R;
di-di-di-dit H; **dit** E; **dit** E;
di-dah-dit R; **dah** T; **di-dah-dit** R;
dah-dah-dah O; **di-di-di-dit** H; **dit** E.

CHECKPOINTS

CHECKPOINT

Letter Groups Exercise:
Say the sound you read for each character . . . then, write down the letter you think it is, and when you've finished writing down the groups of letters . . . check yourself using the "Instant Feedback Cover" as appropriate.

1st: **dit dah di-dah-dit**
dah-dah-dah dit
2nd: **di-di-di-dit di-di-di-dit dit**
dah dah-dah-dah
3rd: **dit di-dah-dit dah-dah-dah**
dah di-di-di-dit
4th: **dah-dah-dah di-dah-dit dit**
di-di-di-dit dah
5th: **dit dah di-dah-dit di-dah-dit**
dah
6th: **dah-dah-dah dit di-di-di-dit**
di-di-di-dit dah
7th: **dah dah dah-dah-dah**
dah-dah-dah dit
8th: **di-dah-dit dah di-di-di-dit**
dah-dah-dah di-dah-dit
9th: **dah di-di-di-dit dit**
di-dah-dit dah-dah-dah
10th: **di-di-di-dit di-dah-dit**
dah-dah-dah dit dit

ANSWERS:

1st:	ETROE	6th:	OEHHT
2nd:	HHETO	7th:	TTOOE
3rd:	EROTH	8th:	RTHOR
4th:	OREHT	9th:	THERO
5th:	ETRRT	10th:	HROEE

How did you do on your first "Letter Groups" exercise? If you feel you still need more practice, don't be afraid to rearrange the practice exercise and try again. For example . . . you might try working from the back to the front, or the middle to the back . . . etc. The main thing is to practice 'till when hearing the sound of a character . . . you automatically think of the character the sound represents.

As you may have guessed . . . this hearing the sound, then writing down its meaning is a "receiving-type" exercise. Let's turn this sequence around and give you a "sending-type" exercise . . . without even using a key. In fact, at this point its better that you don't worry about the mechanics of manipulating a key.

We'll use the same set of characters (letters) for this exercise as we did the receiving exercise. This time, however, we'll give you the character . . . you then are to say the sound for that character . . . then move the "Instant Feedback Cover" down just far enough to see if you sounded it correctly . . . then proceed with the next character, and so on. Wow! This one ought to give you good eye, ear, tongue and manipulative skills coordination. Seriously though, you'll find this exercise to be fun, and not as hard to perform as you might first think. "Try it . . . you'll like it!"

O.K. . . . now that you've got the idea, let's set this up so we can conserve space, and at the same time fix it so that you won't have to move the "Instant Feedback Cover" so far every time to see the correct response. This time we'll put the exercise in a horizontal plane so that you will actually read a letter . . . say the sound . . . then move the cover horizontally (for any given line) to uncover the correct response. This way we can put more than one character on a line and give you more practice in less space. Proceed to the "checkpoints" column and let's try it.

All right! Now that you've seen how to make a practice sending exercise and a practice receiving exercise, we'll let you use your own innovativeness to practice this group of characters as much as you want to, or need to. Here's how: Go back to page 7 where we first listed the "FIRST GROUP OF RANDOM CHARACTERS". Now you can use the "Instant Feedback Cover" to cover either the letter side or the sound ***(di-dah)*** *side, and you then simply randomly jump back and forth through the list either sending or receiving and appropriately uncover the responses as you do.*

CHECKPOINT

Sending-type Exercise

R
di-dah-dit
T
dah
E
dit
O
dah-dah-dah
H
di-di-di-dit

CHECKPOINT

T **dah;** E **dit;** O **dah-dah-dah;**
R **di-dah-dit;** H **di-di-di-dit;** E **dit;**
O **dah-dah-dah;** T **dah;** E **dit;**
E **dit;** H **di-di-di-dit;** H **di-di-di-dit;**
H **di-di-di-dit;** O **dah-dah-dah;** T **dah;**
R **di-dah-dit;** R **di-dah-dit;** E **dit;**
E **dit;** H **di-di-di-dit;** R **di-dah-dit;**
T **dah;** O **dah-dah-dah;**
R **di-dah-dit;** T **dah;** O **dah-dah-dah;**
R **di-dah-dit;** E **dit;** E **dit;**

INFORMATION

Another practice hint (if you are fortunate enough to own a shortwave receiver) is to listen to a "code station" and see if you can pick out the first group characters you have learned. If you are careful to choose a station that is sending good "clean" code (proper spacing and timing), you will find this great sport and excellent practice. Incidentally, if you are considering buying a SW receiver, you might go down to the nearest Radio Shack store and look over the variety they have. Generally you will find that they have an economical receiver that will be excellent for learning code and as a first ham station receiver. If this is not practical at this time, perhaps you can find a friend who has a receiver that you can listen to.

We'll say it again . . . the secret of learning code is practice, practice, practice.

If you've got the first group of letters down so there is no difficulty recognizing their sound patterns—then proceed with the next group we'll introduce you to now. If you still need practice on the first group—then "recycle" yourself as required.

All right! Let's try a "letter groups" exercise for this second group of characters.

SECOND GROUP OF RANDOM CHARACTERS

dah-dah = M
dah-dit = N
di-dah-di-dit = L
di-di-dah-dit = F
di-dah = A
di-dit = I
dah-di-dah-dit = C

Note: Remember to practice each character over and over saying the sound first, then writing and/or pronouncing the letter until you know its sound pattern . . . then move on to the next one. To refresh your memory on how this is done, refer back to the initial exercise for the "FIRST GROUP OF RANDOM CHARACTERS" on page 7.

CHECKPOINT

Say the sound you read for each character . . . then write down the letter you think it is. When you've finished writing down the groups of letters . . . check yourself by using the "Instant Feedback Cover" as appropriate.

LETTER GROUPS EXERCISE

1st: **dah-dah dah-dah dah-dit dah-dit di-dah-di-dit**
2nd: **di-di-dah-dit di-di-dah-dit di-dah-di-dit di-dah di-dit**
3rd: **dah-di-dah-dit dah-di-dah-dit di-dah di-dah di-dit**
4th: **di-dah-di-dit di-dah-di-dit dah-dit di-dah dah-dit**
5th: **dah-di-dah-dit dah-di-dah-dit dah-di-dah-dit dah-di-dah-dit dah-di-dah-dit**
6th: **di-dit di-dit di-di-dah-dit di-dah-di-dit dah-dit**
7th: ***dah-dah di-dah dah-di-dah-dit di-dit di-dah-di-dit***

8th: **di-di-dah-dit di-dah**
dah-di-dah-dit di-dit
di-dah-di-dit
9th: **dah-dah dah-dit di-dah**
dah-dit dah-dah
10th: **di-dit dah-dit di-dah**
dah-di-dah-dit dah-dah

ANSWERS:

1st:	MMNNL	6th:	IIFLN
2nd:	FFLAI	7th:	MACIL
3rd:	CCAAI	8th:	FACIL
4th:	LLNAN	9th:	MNANM
5th:	CCCCC	10th:	INACM

O.K. How did it go? Revert back to the "SECOND GROUP" listing on page 10 and give yourself both receiving and sending practice using the "Instant Feedback Cover" as you did for the 1st group. When you are sure you have the second group well in mind . . . then try combining groups 1 and 2 for practice so you won't forget them. When you are confident that you have the first two groups of letters learned, try the miscellaneous **words** exercise in column 3.

CHECKPOINT

MISCELLANEOUS WORDS EXERCISE

1st: **dah di-di-di-dit dit**
di-di-dah-dit di-dah dah
dah-dah di-dah dah-dit
2nd: **dah-di-dah-dit di-dah dah-dit**
dah-di-dah-dit di-dah dah-dah
di-dah-dit di-dah dah
3rd: **dah-dah di-dah dah**
di-dah-di-dit di-dah dah dit
di-di-di-dit di-dit dah
4th: **di-dah-dit dah-dah-dah dah-dah dit**
dah di-di-di-dit dit di-dah-dit dit
di-di-dah-dit dit dit di-dah-di-dit
5th: **di-di-di-dit dah-dah-dah dah-dah dit**
dah di-dah di-dah-di-dit di-dah-di-dit
dah-dit di-dah dah-dah dit
6th: **dah di-di-di-dit dit di-dit di-dah-dit**
dah-dah-dah di-dah-dit
dah dah-dah-dah dah-dah-dah dah-dit
7th: **dah-dah dah-dah-dah dah di-di-di-dit**
dit di-dah-dit
di-di-dah-dit di-dah dah di-di-di-dit
dit di-dah-dit
di-di-di-dit dit di-dah dah
8th: **dah di-di-di-dit di-dah-dit dit dit**
di-di-dah-dit dit di-dah di-dah-dit
di-dah-dit dah-dah-dah
di-dah-di-dit di-dah-di-dit

INFORMATION

REFERENCE & DATA

CHECKPOINTS

9th: **di-di-dah-dit di-dah di-dit dah**
di-di-di-dit
dah-di-dah-dit di-dah-di-dit dit
di-dah di-dah-dit
di-dah-dit di-dah dah dit
10th: **dah-dah dit di-dah dah-dit**
di-dah-di-dit di-dah dah dit di-dah-dit
dah-di-dah-dit di-dah-dit dit di-dah
dah dit

ANSWERS:
1st: THE FAT MAN
2nd: CAN CAM RAT
3rd: MAT LATE HIT
4th: ROME THERE FEEL
5th: HOME TALL NAME
6th: THEIR OR MOON
7th: MOTHER FATHER HEAT
8th: THREE FEAR ROLL
9th: FAITH CLEAR RATE
10th: MEAN LATER CREATE

How did your first encounter with "real words" go? As you can see, with a little ingenuity, you can develop other word lists using the letters from the first two groups you've learned for further practice.

Let's move on to our third group of random letters now.

Time to try a "letter groups" exercise for this third group of characters.

THIRD GROUP OF RANDOM CHARACTERS

di-di-dit = S
di-dah-dah = W
dah-di-di-dit = B
dah-di-dit = D
dah-dah-dit = G
dah-di-dah-dah = Y
dah-dah-di-dah = Q

Note: Remember to say the sound (**out loud**), then the letter—until you know its sound pattern . . . then move on to the next . . . and so on.

CHECKPOINT

Use the usual procedure here! That is: say the sound . . . then write down the letter you think it is. After completing the exercise, check yourself with the "Instant Feedback Cover".

THIRD LETTER GROUPS EXERCISE

1st: **di-di-dit di-dah-dah di-di-dit**
dah-dah-dit di-di-dit
2nd: **di-dah-dah dah-dah-dit**
di-dah-dah di-di-dit
dah-di-di-dit
3rd: **dah-di-di-dit dah-di-dit**
dah-di-di-dit dah-di-dit
dah-di-di-dit
4th: **dah-di-dit dah-di-di-dit**
dah-di-dah-dah dah-dah-di-dah
dah-di-dah-dah
5th: **di-dah-dah dah-dah-dit**
dah-dah-dit di-dah-dah
dah-dah-di-dah

6th: **di-di-dit dah-di-di-dit**
dah-di-dit dah-dah-dit
dah-di-dah-dah

7th: **dah-di-dah-dah di-dah-dah**
dah-dah-di-dah di-di-dit
dah-di-dit

8th: **dah-di-dit dah-di-di-dit**
dah-dah-dit dah-di-dit
dah-di-dah-dah

9th: **dah-dah-dit di-di-dit**
dah-di-dah-dah dah-dah-di-dah
dah-di-di-dit

10th: **di-di-dit di-dah-dah**
dah-di-di-dit dah-dah-dit
dah-di-dah-dah

ANSWERS:

1st:	SWSGS	6th:	SBDGY
2nd:	WGWSB	7th:	YWQSD
3rd:	BDBDB	8th:	DBGDY
4th:	DBYQY	9th:	GSYQB
5th:	WGGWQ	10th:	SWBGY

Great! If you have the first three groups of letters down . . . you are now ready for the fourth group, which will complete the alphabet. When you know the sound patterns for all the letters in the alphabet—when you hear them in a random fashion . . . you have really accomplished the most difficult part of learning code.

So, let's get at the task of learning the last group of letters for the alphabet. Use the same procedure as you have for the earlier groups. This means saying the sound first for the character, then writing down and/or pronouncing the letter . . . *and repeating this many times,* until you know the sound pattern for that character. After learning it well, then, move on to the next one in the group, and so on, until you know all the letters in the group. After learning all the letters in the group, proceed to the practice exercises for the group.

O.K., let's learn this fourth group.

FOURTH GROUP OF RANDOM CHARACTERS

di-dah-dah-dah = J
dah-di-dah = K
di-dah-dah-dit = P
di-di-dah = U
di-di-di-dah = V
dah-di-di-dah = X
dah-dah-di-dit = Z

Note: Practice these until you know them well . . . then proceed!

Congratulations! You're ready for a letter groups exercise on the *last group of letters you need to learn for the alphabet. Proceed to the third column, and let's get at it!*

CHECKPOINT
FOURTH LETTER GROUPS EXERCISE

1st: di-dah-dah-dah di-dah-dah-dit
di-dah-dah-dit di-dah-dah-dah
dah-di-dah

2nd: dah-di-dah di-dah-dah-dit
dah-di-di-dah dah-di-di-dah
di-dah-dah-dit

3rd: di-dah-dah-dah di-dah-dah-dit
dah-di-dah dah-di-di-dah
dah-di-dah

4th: di-di-dah di-di-di-dah di-di-dah
di-di-di-dah di-di-dah

5th: di-di-di-dah di-dah-dah-dit
dah-di-dah di-dah-dah-dah
di-di-dah

6th: di-di-di-dah di-di-dah
dah-dah-di-dit dah-dah-di-dit
dah-dah-di-dit

7th: dah-dah-di-dit dah-di-di-dah
dah-di-di-dah dah-dah-di-dit
di-dah-dah-dah

8th: di-dah-dah-dit dah-di-dah
di-di-di-dah di-dah-dah-dit
dah-di-dah

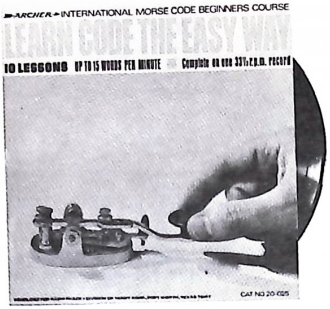
9th: di-dah-dah-dit dah-dah-di-dit
di-di-dah di-di-dah
di-dah-dah-dah

10th: dah-di-dah di-dah-dah-dit
di-di-dah di-di-di-dah
dah-di-di-dah

ANSWERS:

1st:	JPPJK	6th:	VUZZZ
2nd:	KPXXP	7th:	ZXXZJ
3rd:	JPKXK	8th:	PKVPK
4th:	UVUVU	9th:	PZUUJ
5th:	VPKJU	10th:	KPUVX

Hope you did well on this exercise. You have now learned the twenty six letters in the alphabet. Just for good measure, we suggest that you try the sending and receiving practice using the "Instant Feedback Cover" technique on letter groups 3 and 4, just as you did for groups 1 and 2. After you are sure you have all twenty six letter sound patterns pretty well in mind, we want you to try the "mixed code groups" practice in the exercise shown in the third column. When you're ready . . . give it a try.


ARCHER • INTERNATIONAL MORSE CODE BEGINNERS COURSE
LEARN CODE THE EASY WAY
10 LESSONS UP TO 15 WORDS PER MINUTE
CAT NO 20-025

Now you've worked with the "sounds of code" and you should recognize each letter. We urge you to use a learning aid such as the Code Record illustrated above. It's available at your local Radio Shack store.

TOTAL ALPHABET MIXED CODE GROUPS EXERCISE

1st: di-dah dah-di-dah-dit dit
dah-dah-dit di-dit

2nd: dah-di-dah dah-dah
dah-dah-dah dah-dah-di-dah
di-di-dit

3rd: di-di-dah di-dah-dah
dah-di-dah-dah dah-dah-di-dit
dah-di-di-dah

4th: di-di-di-dah dah di-dah-dit
di-dah-dah-dit dah-dit

5th: di-dah-di-dit di-dah-dah-dah
di-di-di-dit di-di-dah-dit
dah-di-dit

6th: dah-di-di-dit di-dah dah-di-dit
dah-dah-dit di-dah-dah-dah

7th: dah-dah di-dah-dah-dit
di-di-dit di-di-di-dah
dah-di-dah-dah

8th: dah-dah-di-dit di-dah
dah-di-di-dit dah-di-dah-dit
dah-di-dit

9th: dah-dah-dah di-dah-dah-dit
dah-dah-di-dah di-dah-dit
di-di-dit

10th: di-dah-dah-dah dah-di-dah
di-dah-di-dit dah-dah dah-dit

11th: dit di-di-dah-dit dah-dah-dit
di-di-di-dit di-dit

12th: dah-di-dah-dah dah-dah-di-dit
di-dah dah-di-di-dit
dah-di-dah-dit

13th: dah di-di-dah di-di-di-dah
di-dah-dah dah-di-di-dah

14th: di-dah di-di-dah di-di-di-dah
dah-dah dah-dit

15th: dah dah-dah-dah
dah-di-dah-dit dah-di-dah-dit dit

16th: dit di-dit di-di-dit di-di-di-dit dah

ANSWERS:

1st: ACEGI
2nd: KMOQS
3rd: UWYZX
4th: VTRPN
5th: LJHFD
6th: BADGJ
7th: MPSVY
8th: ZABCD
9th: OPQRS
10th: JKLMN
11th: EFGHI
12th: YZABC
13th: TUVWX
14th: AUVMN
15th: TOCCE
16th: EISHT

INFORMATION

How did it go? You should have detected from this exercise the letters you are weak on. You should, of course, work on your weak ones until you have them as well as the others. Let's say again, the secret is PRACTICE! PRACTICE! PRACTICE! "Off the air" practice in receiving is really the best . . . providing you listen to a station sending "clean" code. The best way to do this at this point in your learning process is to listen to some of station W1AW's code practice transmissions.

If you don't have a receiver that will receive these frequencies you might want to run down to your nearest Radio Shack and look over their selection. As we said before . . . the best practice in the world is **listening** to the sounds . . . and listening to them being **well sent** . . . so get a receiver, or the use of one if at all possible. Take advantage of the premium practice available from W1AW. You'll find that you will progress much faster in code if you'll do this. Good luck!

As you listen to radio stations sending code, you will discover that they send other characters than just the 26 letters in the alphabet. For that reason, let's move into the area of learning the numbers and important punctuation. By the time you learn these . . . if you have been faithfully practicing . . . you should be ready to take the Novice Class License Code test.

Here's the numbers study list. See if you can determine the unique pattern of sounds that were developed for communicating the numbers via code.

Did you catch the logical pattern that was developed for the numbers? WATCH OUT THOUGH! The temptation is going to be to "count" the dits or dahs . . . then try and think out which of the numbers it is. You must learn to hear the TOTAL CHARACTER SOUND as one unique sound you recognize, and do no start counting the elements which make up a character.

REFERENCE & DATA

W1AW CODE PRACTICE SCHEDULE

Practice is transmitted three times a day during the weekdays and twice a day on the weekends. On weekdays, the times are 9:00 A.M. EST, 7:30 P.M. EST and 9:30 P.M. EST, and on weekends the P.M. schedules are maintained. For the beginner, the best times for listening are: 9:00 A.M. Monday, Wednesday, and Friday and 9:30 P.M. on Sundays, Tuesdays, Thursdays, and Saturdays. At these times W1AW sends practice at speeds of 5, 7½, 10, 13, 20 and 25 WPM (words per minute). As you progress you will find that the 7:30 schedule EVERY night is a good one as they send at 10, 13 and 15 WPM for practice purposes. All these transmissions are made simultaneously on the following frequencies: 1805, 3580, 7080, 14,080, 21,080, 28,080, 50,080 and 145,588 kHz. (If your receiver dial is calibrated in Megacycles, Mc., or Megahertz, MHz., simply put the decimal point in the above named frequencies BACK three places from the right. For example 14,080 kHz = 14.08 Mc. or MHz.)

NUMBERS

di-dah-dah-dah-dah = 1
di-di-dah-dah-dah = 2
di-di-di-dah-dah = 3
di-di-di-di-dah = 4
di-di-di-di-dit = 5
dah-di-di-di-dit = 6
dah-dah-di-di-dit = 7
dah-dah-dah-di-dit = 8
dah-dah-dah-dah-dit = 9
dah-dah-dah-dah-dah = **ϕ** (this is the way we write zero to avoid confusion with the letter **O**)

CHECKPOINTS

Use the usual procedure of "receiving" practice first, until you know all the characters well . . . i.e. say the sound, then write down what it means . . . then proceed to "sending" practice by covering the sounds with the "Instant Feedback Cover" and while looking at the numbers in a random fashion, say, or whistle the appropriate sound for them.

When you are sure you have the numbers well cataloged in your "biological computer" BY SOUND, proceed on the next job at hand . . . that is, learning some of the more frequently used punctuation.

PUNCTUATION COMMONLY USED IN CODE MESSAGES

di-dah-di-dah-di-dah	= PERIOD
dah-dah-di-di-dah-dah	= COMMA
di-di-dah-dah-di-dit	= QUESTION MARK
dah-di-di-di-dah	= DOUBLE DASH (sometimes written as $\overline{BT}$)
di-dah-di-dah-dit	= END OF MESSAGE (sometimes written as $\overline{AR}$)
di-di-di-dah-di-dah	= END OF WORK (or transmission
dah-di-di-dah-dit	= FRACTION BAR (diagonal slant mark)

Note: Practice these the usual way. It is noteworthy, however, that on the NOVICE CLASS license code receiving test you will not be required to receive punctuation . . . BUT, you may be required to send punctuation during the SENDING portion of the test . . . so it won't hurt to go ahead and learn them, and get them out of the way, since for General Class you'll need to know them anyway.

O.K.! Let's "put it all together!" Try this "put it all together" exercise of letters, numbers, and punctuation. Consider this your **receiving** "Final Checkout" for the "Learning the International Morse Code" chapter. If you "ACE" this one; you're well on your way to getting that first Amateur Radio License.

Code Receiving Checkout—Conglomerate of Straight Text, Mixed Ciphers, Numbers and Punctuation

Line 1—dah di-di-di-dit di-dit
di-di-dit di-dit di-di-dit

Line 2—di-dah di-di-dah dah-dit
di-dit dah-dah-di-dah
di-di-dah dit

Line 3—dah-di-dah-dit dah-dah-dah
dah-dit dah-dah-dit
di-dah-di-dit

Line 4—dah-dah-dah dah-dah dit
di-dah-dit di-dah dah
di-dit

Line 5—dah-dah-dah dah-dit
dah-dah-dah di-di-dah-dit

Line 6—di-dah-dah dah-dah-dah
di-dah-dit dah-di-dit
di-di-dit

Line 7—dah-dah-di-di-dah-dah
dah-dah di-dit dah-di-di-dah

Line 8—dit dah-di-dit dah-di-dah-dit
di-dit di-dah-dah-dit

Line 9—di-di-di-dit dit di-dah-dit
di-di-dit dah-dah-di-di-dah-dah

Line 10—dah-dit di-di-dah dah-dah
dah-di-di-dit dit di-dah-dit
di-di-dit

Line 11—di-dah dah-dit dah-di-dit
di-dah-dah-dit

Line 12—di-di-dah dah-dit
dah-di-dah-dit dah
di-di-dah di-dah

Line 13—dah di-dit dah-dah-dah
dah-dit di-dah-di-dah-di-dah

Line 14—di-dit di-di-dah-dit
dah-di-dah-dah dah-dah-dah
di-di-dah

Line 15—dah-dah-dit dit dah
dah-di-dah-dit dah-di-dah-dit
dah-dah-dit

Line 16—dit dah di-dah-dah-dah-dah
dah-dah-dah-dah-dah
dah-dah-dah-dah-dah

Line 17—di-dah-dah-dit dit di-dah-dit
dah-di-dah-dit dit dah-dit
dah

Line 18—dah-dah-di-di-dah-dah
dah-di-dah-dah dah-dah-dah
di-di-dah

Line 19—di-di-di-dit di-dah
di-di-di-dah dit

Line 20—dah-di-dit dah-dah-dah
dah-dit dit di-dah dah-dit

Line 21—dit dah-di-di-dah
dah-di-dah-dit dit
di-dah-di-dit di-dah-di-dit

Line 22—dit dah-dit dah
di-dah-dah-dah dah-dah-dah
dah-di-di-dit

Line 23—dah-dah-dah di-di-dah-dit
di-dah-di-dit dit di-dah
di-dah-dit

Line 24—dah-dit di-dit dah-dit
dah-dah-dit dah di-di-di-dit
dit

Line 25—dah-di-dah-dit dah-dah-dah
dah-di-dit dit
di-dah-di-dah-di-dah

Line 26—dah-dit dah-dah-dah
di-dah-dah
dah-dah-di-di-dah-dah

Line 27—di-dah di-dah-di-dit
di-dah-di-dit dah-di-dah-dah
dah-dah-dah

Line 28—di-di-dah dah-dit dit dit
dah-di-dit dah
dah-dah-dah

Line 29—dah-di-dit dah-dah-dah
di-dit di-di-dit
dah-di-dah-dit

Line 30—dah-dah-dah dah-dit dah
di-dit dah-dit di-di-dah
dit

Line 31—di-dah-dah-dit di-dah-dit
di-dah dah-di-dah-dit
dah di-dit

Line 32—dah-di-dah-dit di-dit
dah-dit dah-dah-dit di-dit
dah-dit

Line 33—dah-dah-dah di-dah-dit
dah-di-dit dit di-dah-dit

Line 34—dah dah-dah-dah di-dit
dah-dit dah-di-dah-dit
di-dah-dit

Line 35—dit di-dah di-di-dit dit
dah-di-dah-dah dah-dah-dah

Line 36—di-di-dah di-dah-dit di-di-dit
di-dah-dah-dit dit dit
dah-di-dit

Line 37—di-dah-di-dah-di-dah
dah-dah-di-dah
di-di-dah-dah-dah

Line 38—di-di-di-di-dit
dah-dah-dah-dah-dah
dah-di-di-dit dah

Line 39—dah-dah di-dah-dah-dit
di-di-dit di-di-di-dah-dah
dah-dah

Line 40—dah-di-di-di-dit
di-dah-dah-dah dah-di-di-di-dah

Line 41—di-dah-di-dah-dit dah dah-dit
dah-di-di-dah

Line 42—di-di-dah-dit dit di-dah-dit
dah di-di-di-dit dit

Line 43—dah-dah-di-dah di-di-dit
dah-dah-dah dah-dah-dah
dah-dah

Line 44—di-dah-di-dah-di-dah dah-dah
dah-di-dah-dah

Line 45—di-di-dit di-dit dah-dah-dit
di-di-dit

Line 46—di-dah-dah dit di-dah-dit
dit dah-dit dah-dah-dah dah

Line 47—di-dah-dah-dah-dah
dah-di-di-dah-dit
di-di-dah-dah-dah

Line 48—di-dah di-di-dit dah-dah-dit
dah-dah-dah dah-dah-dah
dah-di-dit

Line 49—di-dah di-di-dit
dah-di-dah-dah dah-dah-dah
di-di-dah

Line 50—di-dah-dit di-di-dit
dah-dah-di-di-dah-dah

Line 51—di-dah-dah dit di-dah-dit
dit dah di-di-di-dit dit

Line 52—dah-di-dah-dah
di-di-dah-dah-di-dit

Line 53—di-di-di-dit dah-dah-dah
di-dah-dah-dit dit

Line 54—dah-di-dah-dah dah-dah-dah
di-di-dah

Line 55—dah-di-dah-dit dah-dah-di-dah
dah-di-dah-dit dah-dah-di-dah

Line 56—dah-di-dah-dit dah-dah-di-dah
dah-dah di-dah dah-di-dit
dit

Line 57—dah-dah-dah-dah-dit
dah-dah-dah-di-dit
dah-dah-di-di-dit

Line 58—dah-dah-dah di-di-dah dah
di-dah-dah dit di-dah-di-dit

Line 59—di-dah-di-dit dah-dah-dah
dah-dit dah di-di-di-dit
di-dit

Line 60—di-di-dit dah-di-dah-dit
di-di-di-dit dit
dah-di-dah-dit

Line 61—dah-di-dah dah-dah-dah
di-di-dah dah
di-dah-di-dah-di-dah

Line 62—di-dit di-di-dah-dit
dah-di-dah-dah dah-dah-dah
di-di-dah

Line 63—dah-dah di-dah dah-di-dit
dit dah-dah-dah-dah-dit
dah-dah-dah-dah-dah

Line 64—di-dah-dah-dit dit di-dah-dit
dah-di-dah-dit dit
dah-dit dah

Line 65—dah-dah-dah di-dah-dit
di-dah-di-dit dit di-di-dit
di-di-dit

Line 66—dah-dah-di-di-dah-dah
dah-di-dah-dah dah-dah-dah
di-di-dah

Line 67—di-dah-dah-dit di-dah-dit
dah-dah-dah dah-di-di-dit
di-dah

Line 68—dah-di-di-dit di-dah-di-dit
dah-di-dah-dah

Line 69—dah-dit dit dit dah-di-dit
dah-dah dah-dah-dah
di-dah-dit dit

Line 70—dah-di-di-di-dah di-dah-dah-dit
di-dah-dit di-dah

Line 71—dah-di-dah-dit dah di-dit
dah-di-dah-dit dit

Line 72—dah-di-di-di-dah
dah-dah-di-di-dah-dah

Line 73—dah-di-di-dah-dit
di-di-di-dah-di-dah

ANSWERS:

Line 1= This is
Line 2= a unique
Line 3= congl
Line 4= omerati
Line 5= on of
Line 6= words
Line 7= , mix
Line 8= ed cip
Line 9= hers,
Line 10= numbers
Line 11= and p
Line 12= unctua
Line 13= tion.
Line 14= If you
Line 15= get CCG
Line 16= ET 100
Line 17= per cent
Line 18= , you
Line 19= have
Line 20= done an
Line 21= excell
Line 22= ent job
Line 23= of lear
Line 24= ning the
Line 25= code.
Line 26= Now,
Line 27= all yo
Line 28= u need to
Line 29= do is c
Line 30= ontinue
Line 31= practi
Line 32= cing in
Line 33= order
Line 34= to incr
Line 35= ease yo
Line 36= ur speed
Line 37= . Q2
Line 38= 50 BT
Line 39= MPS 3M
Line 40= 6$\overline{\text{BT}}$
Line 41= $\overline{\text{AR}}$ TNX
Line 42= fer the
Line 43= QSO OM
Line 44= . My
Line 45= sigs
Line 46= were not
Line 47= 1/2
Line 48= as good
Line 49= as you
Line 50= rs,
Line 51= were the
Line 52= y?
Line 53= Hope
Line 54= you
Line 55= CQ CQ
Line 56= CQ made
Line 57= 987
Line 58= out wel
Line 59= l on thi
Line 60= s chec
Line 61= kout.
Line 62= If you
Line 63= made 90
Line 64= per cent
Line 65= or less
Line 66= , you
Line 67= proba
Line 68= bly
Line 69= need more
Line 70= $\overline{\text{BT}}$ pra
Line 71= ctice
Line 72= $\overline{\text{BT}}$
Line 73=/ $\overline{\text{SK}}$ (end of transmission)
(or, end of work)

Wow! That was some checkout! How did you do? Of course, this checkout isn't really as good as listening to GOOD code and copying "off the air" on a receiver. The advantage here, however, is that you can check yourself. Even when listening to a receiver . . . you can generally tell if you are copying or not. Remember our "pass" word for code is PRACTICE!

PRACTICE when you're riding in a car or walking by translating the signs you read into code sounds (either sounded or whistled properly) . . . indeed, practice at any and every opportunity . . . you'll be surprised that this "sneaked-in" practice helps you get to your goal much, much faster.

Now we want to give you some . . .

HINTS FOR SENDING CODE WITH A KEY

We have delayed until now getting you involved with a code key because it is an absolute necessity that you KNOW THE SOUND OF CORRECTLY SENT CODE before you can "mimic" these sounds with your own sending.

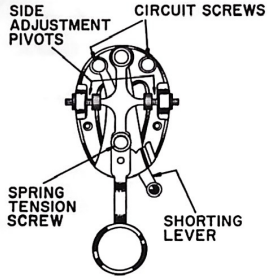
Three things are of paramount importance in regard to the "mechanics" of using a code key well. These are:

1. Proper adjustment of the key action. (spring tension, side play and up and down movement, i.e., how far the key knob moves from the unpressed position to the fully depressed position).

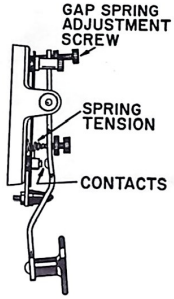
2. Proper body posture and position.

3. A comfortable "fluid" movement of the wrist and hand while sending, rather than a tense and tiring use of the muscles involved.

Let's look at these items one at a time.



Note: *Adjust side adjustment pivots for good contact alignment and so the key does not bind; but no so loose that the key can have "slop" sideways. Generally, the best way to do this is to tighten pivots until "snug", then back off just a "tad". Adjust the Spring tension adjustment for a moderately heavy tension. In other words . . . don't have "hair trigger" action when pushing the key knob . . . but don't have tension so hard it will tire you quickly when repeatedly depressing the key.*



Note: *Generally, when beginning to learn use of the key, it is best to have a wider spacing between the contacts than later on, when you become more proficient. A good rule of thumb for a beginner might be about 1/16" contact gap. As you increase in proficiency, you can decrease this gap slightly.*

Next on our list was "proper body posture and position".

Sit upright in your chair and "square" with the operating table. Position the key far enough in front of you so you have room to rest your elbow on the table. Grasp the key knob with your thumb on the left edge of the key, your index and middle finger resting comfortably toward the front edge of the knob, and your fourth and little finger curled loosely "out of the way". Notice that the fingers, hand and wrist form a natural, slight arch, and the forearm is resting on the table. The goal here is to get a position THAT IS COMFORTABLE TO YOU. The position shown should be about it.

We've already shown you the correct position . . . but take a look at some of these comic grips some people actually fall into. Don't you be one of them!

Now about our third point regarding the "fluid" movement of wrist and hand. You actually "set the stage" for this proper movement by using the proper position and posture for your body as discussed earlier.

The thing we want to mention here is don't be tense in the forearm and wrist . . . and don't push the key down using your whole arm. More or less use your forearm as the fulcrum, and let a slight up and down motion of the wrist and hand do the work.

O.K. Let's talk about some possible hints for practicing. At first you should practice sending "strings" of "dits" and "dahs" until you can send them smoothly using the proper time between elements. Avoid making each element in a character (dot and dash) "choppy".

Also, beware of "slurring" the elements together, or "slurring" the characters together. If you have a tendency to be "choppy", chances are the spring tension on the key is too tight. If slurring is a problem, maybe the spring tension it too loose. Only you can judge when the position you use and the key adjustments "feel right".

INFORMATION

After you practice series of dits and dahs until you think they sound right, and you don't tire because of the wrong position or wrist action, then you are ready to move on to some specific character practice.

The ARRL booklet entitled, "Learning the Radiotelegraph Code" gives some good hints along these lines. In fact, you will find that many useful ideas are given in this booklet for both receiving and sending.

This booklet suggests the following groups for sending practice. The reason they are grouped as shown is obvious when you analyze the relationships of the character sounds included in each group.

Try these exercises until you can comfortably send all the characters.

Believe it or not . . . saying the sounds for signs along the road, etc., can help you in learning to send. Make a habit of translating on sight, any letters you see, into code sounds. Even though this will not help you with the mechanics of "pushing the key down" . . . it will help develop a proper sense of rhythm and timing which is imperative for good sending of code.

Again . . . NOTHING WILL TAKE THE PLACE OF PRACTICE! Practice with the key until it is second nature to translate written letters, words and sentences into natural wrist, hand and arm movements to produce the appropriate sounds. Look at some of the sending practice aids shown in the next column. Get some of these aids and use them! Use them! Use them!

WHAT THIS CHAPTER SAYS . . . IN "CAPSULE" FORM

1. ***You can only learn code by sound,*** *if you want to learn it properly.*
2. *You can only learn code by* ***practice, practice, practice!***
3. *Learn to receive code and recognize good code* ***before*** *trying to use a code key.*
4. *If at all possible . . . listen to good code (copy it) "off the air." Note some of the "receiving" system equipment Radio Shack carries shown in the next column. Also, refer back to page 16 for practice schedules from W1AW.*
5. ***Practice at every opportunity***—translating signs, etc., into code sounds.
6. When sending code with a key, observe: 1. Proper key adjustment, 2. Proper body position and posture, 3. Comfortable gripping and moving of the key for a fluid sending movement.
7. Don't get impatient and give up! Code comes easier to some than others, but it will come to everyone who will continue to practice.

REFERENCE & DATA

Group 1: E, I, S, H and 5.

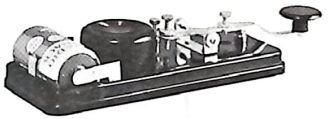
Group 2: T, M, O and ϕ (remember this is the way we write zero)

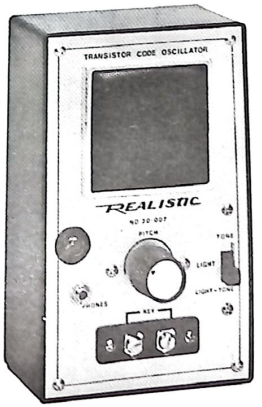
Group 3: A, R, L, W, J, I and P

Group 4: U, F, 2, V, 3 and 4

Group 5: N, D, B, 6, 8, 9 and X

Group 6: G, Q, Z, 7, K, C and Y





CHECKPOINTS

Chapter 2

GETTING THE NOVICE CLASS LICENSE

We commend you for sticking at the code. Even while studying the remainder of this book, keep at your code practice, and your code speed will probably correlate to the level exam you are studying for. For example, if you have faithfully gone through the "rigors" of the code program laid out for you in the previous chapter, you probably can pass the Novice Class Code test in good fashion. Let's move ahead now to preparing you for the "written" portion of the Novice exam.

WHAT IS THE NOVICE CLASS, AND WHAT PRIVILEGES WILL YOU HAVE?

It is a great way to break into Ham radio! The FCC has provided this class license in order to encourage people to get involved with Ham radio. The written test is relatively simple, and the code requirements are minimal. Although requirements are minimal . . . the excitement of a contact on the Novice bands is "not one iota less" than tremendous. In fact, as I recall my first contact as a Novice, I believe I can honestly say, it was the most exciting contact I've ever made. Just to send out that CQ CQ CQ and the station call letters, and then hear someone sending your call letters right back at you is probably one of the most exhilarating experiences you will ever have.

The requirements for acquiring a Novice Class license are:

1. Passing a code test in sending and receiving at a rate of 5 words per minute.

2. Passing a written examination covering elementary aspects of amateur radio theory and regulations.

Your privileges will be to send and receive communications by means of code on four of the Amateur bands. (80 meters, 40 meters, 15 meters and 10 meters). The specific frequency spectrums in which you can do this are shown in the next column.

What in the world do we mean by **80 meters, 40 meters,** etc.? First you should be made aware that radio waves travel at the speed of light, which is approximately 186,000 miles per SECOND. If you were to translate those miles into meters, you'd find that RF (radio frequency) energy travels at about 300,000,000 meters per second.

O.K., how does that relate to 80 meters . . . etc.? Well, RF energy is comprised of electrical voltages and currents (parameters) which increase and decrease in a repetitious manner. Each time a voltage or current starts repeating what it has already done before, we say that a new "cycle" has begun. Speaking of cycle, think about a bicycle wheel. If we start with the front tire valve stem straight up and down at the bottom of the wheel, then roll until it reaches that same position again, we can say the wheel has gone through one cycle.

NOVICE BAND FREQUENCIES

80 meters—3700-3750 kHz
40 meters—7100-7150 kHz
15 meters—21.1-21.2 MHz
10 meters—28.1-28.2 MHz

Note: Only C.W. (code) transmissions can be used. The FCC calls this "A-1" type transmission.

INFORMATION

Radio Frequency voltage and current complete many many cycles in one second. In fact we designate the frequency of a radio wave as being so many cycles per second. If you rode your bicycle so that the wheel rotated 2 times in 1 second, we might say that frequency of rotation was 2 cycles per second.

Now, since Mr. Hertz, a German scientist, was instrumental in early knowledge about radio waves and their propagation, the scientific world has honored him by naming the "cycle" of electrical energy in his name. Nowadays it is correct to say our house current has a frequency of 60 **Hertz,** rather than saying 60 cycles per second . . . and it means the same thing.

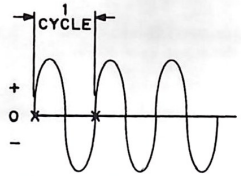
All right, if an RF wave has a frequency of 1 million Hertz; how long do you think one cycle takes? If you figured 1 **millionth** of a second . . . you were right! Since you were so smart on that one . . . try this one in your "biological computer". If Radio energy travels at a rate of speed of 300,000,000 meters per second . . . how far would our 1,000,000 Hertz signal get in the time it takes for one cycle? You should be thinking to yourself . . . If one cycle takes one millionth of a second . . . and the energy travels at a rate of 300 million meters per second, then, in one millionth of a second the RF "signal" should have traveled one millionth of 300 million meters . . . or 300 meters. This signal then might be called a 300 meter signal.

Now, back to our 80 meter, 40 meter, etc. signals. When we say that the Novice Band frequencies between 3700-3750 thousand Hertz (kHz for kilo-Hertz) are in the 80 meter band . . . it is just an approximation of how far that frequency signal will travel in the time it takes for one cycle of that signal, traveling at the speed of light (300,000,000 meters/second) of course, this is not an exact statement, because one, and only one precise frequency will travel that exact distance during the time of one cycle (or Hertz) of itself. Anyway, you get the idea. The "40 meter band" are frequencies whose RF energy will travel about 40 meters in the time it takes for one cycle (or Hertz) of that energy.

This brings us to another new term . . . **wavelength.** *A wavelength is also the distance a wave will travel during the time of one cycle. Look at the formula in the next column which shows the relationship of frequency and wavelength.*

Now, what this says to us is that the higher the frequency, the shorter the wavelength, and vice-versa. Try the problem in the third column to see if you have the idea.

REFERENCE & DATA



RF VOLTAGE AND CURRENT "WAVEFORM"

BETTMANN ARCHIVE, INC.

HEINRICH HERTZ

Formula

Distance = Speed x Time

Example:
Distance RF energy of 1,000,000 Hertz frequency travels during time for 1 Hertz

(Speed) x **(Time)**

1 Hz = 300,000,000 Meters/Sec x 0.000,001 Second

= 300 Meters

Formula

$$\text{Wavelength} = \frac{300{,}000{,}000}{\text{Frequency in Hertz}}$$

AS "F" (frequency) ↑
λ (wavelength) ↓

Note: This type of relationship is often referred to as an **inverse** relationship; that is, if one factor increases, the other decreases, and vice-versa. Remember this term: **inverse.**

CHECKPOINTS

CHECKPOINT

Given: Frequency = 15 million Hertz. What is the wavelength? _____Meters.

ANSWER:

Wavelength = $\frac{300,000,000}{15,000,000}$ = 20 meters

How'd you do? Those numbers are a bit cumbersome aren't they? Since radio signals are in the thousands and millions of hertz, it will be helpful right here to introduce you to some "shorthand" for these big numbers. Most of us have heard of a meter, and a kilometer as used for distances in Europe. As you know, a kilometer is simply 1000 meters. The prefix "kilo" means 1000. When we talk about an RF signal of 10 kilohertz, we mean a signal of 10,000 Hertz, or 20 kilohertz (abbreviated kHz) we mean 20,000 Hertz, and so on. Since in amateur radio we generally are speaking of frequencies of millions of Hertz, let's learn one other metric term . . . "Mega", which when used as a prefix means a million. Thus, if I am talking about an RF signal of 10 Megahertz (abbreviated MHz), I mean a signal whose frequency is 10,000,000 Hertz. Now, you convert some frequencies as shown in the third column to see if you understand these prefixes.

CHECKPOINT

2.5 MHz = _____ Hz
1000 Hz = _____ kHz
1 kHz = _____ MHz
1.6 MHz = _____ kHz

ANSWERS:

2.5 MHz = 2,500,000 Hz
1000 Hz = 1 kHz
1 kHz = 0.001 MHz
1.6 MHz = 1,600 kHz

Did you see the pattern? To change kHz to MHz, simply move the decimal point three places to the left. To change MHz to kHz, simply move the decimal point three places to the right. This is true because a MHz is 1000 times greater than a kHz . . . or, conversely, a kHz is 1000 times smaller than a MHz. Try the checkpoint.

CHECKPOINT

How many times greater than a Hertz
is a MHz?_____ times:
a kHz?_____ times.

ANSWERS:

MHz = 1 million times greater
kHz = 1 thousand times

Get it right? In essence all that is happening is you are multiplying by one thousand, or one million . . . or dividing by one thousand, or one million in order to convert. When you move the decimal point three places to the left, you have effectively divided by 1 thousand, or three places to the right, you have multiplied by a thousand. Since a Hertz is only one thousandth of a kHz . . . if I were converting Hertz to kHz, should I move the decimal to the right or left? The answer is to the left. Example:
1000 Hertz = 1.000 kHz.

Study the chart in the second column until you understand these conversions thoroughly. Many FCC tests require you to be able to do this.

TO CONVERT	TO	MOVE THE DECIMAL
units	kilo-units	3 places to left
units	mega-units	6 places to left
kilo-units	units	3 places to right
mega-units	units	6 places to right
kilo-units	mega-units	3 places to left
mega-units	kilo-units	3 places to right

INFORMATION

Try this last practice exercise to see if you have the idea.

REFERENCE & DATA

CHECKPOINTS

CHECKPOINT

Convert the following as required:

2 MHz = _____ kHz
1000 kHz = _____ MHz
1000 kHz = _____ Hz
1,540,000 Hz = _____ MHz
1,540,000 Hz = _____ kHz
2,546 MHz = _____ kHz
1.65 kHz = _____ Hertz (Hz)

ANSWERS:
2 MHz = 2,000 kHz
1000 kHz = 1 MHz
1000 kHz = 1,000,000 Hz
1,540,000 Hz = 1.54 MHz
1,540,000 Hz = 1,540 kHz
2,546 MHz = 2,546 kHz
1.65 kHz = 1,650 Hz

Did you make out all right? May we suggest that you ***don't memorize*** *the conversion chart, but rather UNDERSTAND what is happening when you convert. In fact, let's make a general statement here regarding all the "theory" and formulas you'll be learning as you go through this book. It is always better to study a formula, or point of theory until you UNDERSTAND THE CONCEPT . . . rather than using "rote memory" methods and depending upon your ability to recall needed information. If you really do understand the concept . . . you can then "figure out" the formula, or conversion factor, etc., as required. If you understand that a Megahertz is 1000 times greater than a Kilohertz, you can figure out that 1 MHz must equal 1000 kHz, and so on.*

Now that we have gotten some preliminary information out of the way, and you have a general idea what the Novice Bands mean in terms of frequency and wavelength, and know the general requirements for, and privileges of being a Novice . . . let's get to the "nitty gritty", and begin learning some Electronic theory.

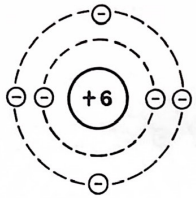
First, let's find out "what in the world the matter is"! By this poor bit of humor I simply want to say, let's take a quick look at the atom . . . of which all matter is composed. The chair you are sitting on, the book you are reading, etc., are all made up of tiny particles called **atoms.** Now the atom is a little galaxy all its own. In the center is the greatest mass, called the **nucleus.** The nucleus is composed of particles called **protons** . . . which have a positive electrical charge, and **neutrons** which are neutral electrically.

Reminder . . . working on your code? Don't forget it. A Code Practice Oscillator like the one illustrated above is a great aid to learn code. Available at your Radio Shack store.

outc hell rons d to insul s or

Around this nucleus are some **orbiting** particles called **electrons**, which are electrically considered as negatively charged particles. The number of orbiting electrons, for an atom which hasn't gained or lost any electrons due to some external force, or energy, will exactly equal the number of protons (positively charged particles) in the nucleus of the atom. Observe the diagram of the electrically "balanced" atom of carbon in the next column. Note the heavy circle in the center represents the nucleus with its six positive charges, or protons. The little circles with the minus signs in them which are orbiting the nucleus are the electrons.

Without looking back into this column for the answers, try the checkpoint in column 3.



CARBON ATOM

CHECKPOINT

The smallest particle of matter which contains the characteristics of the given material is called an _____. This particle is made up of three types of smaller particles, which are: the _____, which are positively charged particles, the nuetrons which are electrically _____ and the _____ which are negatively charged particles.

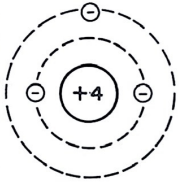
The nucleus is composed of _____ and _____. The orbiting particles are called _____ and are _____ charged.

ANSWERS:
The smallest particle of matter which contains the characteristics of the given material is called an **(atom)**. This particle is made up of three types of smaller particles, which are: the **(protons)**, which are positively charged particles; the neutrons, which are electrically **(neutral)** and the **(electrons)**, which are negatively charged particles.

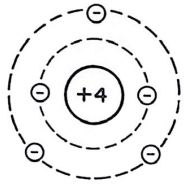
The nucleus is composed of **(protrons)** and **(neutrons)**. The orbiting particles are called **(electrons)** and are **(negatively)** charged.

O.K.! Hope you've got the particles in an atom straight in your mind. The most important ones to remember are the **electrons** and **protons.** The reason for this is that when an atom is "electrically balanced", there are the same number of orbiting electrons as there are protons in the nucleus. However, if by some form of energy (whether chemical, heat, light, etc.) a situation is developed where this is not true—the atom is no longer electrically neutral, but has a net **charge.** An atom in which this unbalance has occurred is called an **ion.** If the atom has lost electrons (has fewer electrons than protons) it is called a **positive ion.** If the atom has gained "extra" electrons, it is said to be negatively charged, and is called a **negative ion.**

Try the checkpoint!



POSITIVE ION



NEGATIVE ION

CHECKPOINT

The atoms in this paper have the same number of electrons and protrons; therefore, these atoms are electrically _____.

An atom which has gained "extra" electrons is called a _____ ion; whereas, an atom which has too few electrons can be called a _____ _____.

ANSWERS:
The atoms in this paper have the same number of electrons as protons; therefore, this paper is electrically **(neutral)**. An atom which has gained "extra" electrons is called a **(negative)** ion; whereas, an atom which has too few electrons can be called a **(positive) (ion)**.

INFORMATION

The fact that we can by various forms of energy cause this electrical unbalance allows the production of **electricity** and various electrical phenomena. To "separate" these charges in an atom (or group of atoms) requires work . . . and that is why we mentioned the use of various forms of energy. The battery or cell utilizes chemical energy to separate charges and produce an excess of electrons at its **negative terminal** and an excess of protons at its **positive terminal.** The generator, or alternator in our automobile uses mechanical energy to perform this work of "generating electricity" by moving **charges.** Other devices may use heat, or light energy, and so on.

REFERENCE & DATA

CHECKPOINTS

CHECKPOINT

Several forms of energy that can be used to "move electrons" and produce electricity are: _____, _____, _____ and _____ energy.

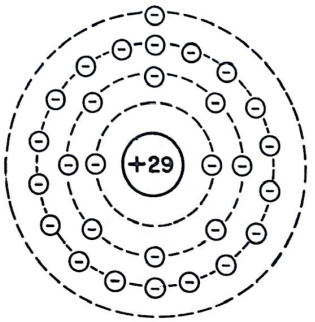
ANSWERS:
Several forms of energy that can be used to "move electrons" and produce electricity are: **(chemical), (mechanical), (heat) or (Thermal)** and **(light)** energy.

O.K., How does all this relate to electricity and electronics! Let's start by seeing what causes some materials to be good electrical conductors, while others are poor conductors, but good insulators; and still others are not real good conductors or insulators, but are classified as "semiconductors".

You may have noticed in our previous sketches of atoms, the orbiting electrons were not all in one ring, or shell (orbiting path). It is beyond the scope of this book to go into the chemical or atomic reasons for this, but we do want to touch on a couple of important facts regarding this.

The "electrical stability" of an atom is determined by this orbital "layout" of electrons. The most important group of electrons, for our consideration, are the ones in the "ring" farthest from the nucleus . . . or the "outer shell". For any atom . . . the "magic number" of electrons that will cause complete electrical "stability" is 8 in this outermost ring. All atoms also have the stipulation that no more than 2 electrons can appear in the "innermost ring". Thus, the carbon atom we showed you is not completely stable, or "inert", since it has only 4 outer ring electrons. Of course, the other 2 electrons appear in the inner ring. If a material has 4 electrons in its outer ring, it is categorized as a semiconductor. If the material's atomic structure is such that there are fewer than 4 electrons in its outer ring, it is usually classed as a conductor; and if more than 4 electrons are in its outer shell, it is generally an insulator, or non-conductor.

Look at the diagram of the copper atom. Notice that is has 29 protons in its nucleus; therefore must normally have 29 orbiting electrons. Due to the laws of nature, we find that the innermost ring is considered "filled" when it has two electrons, the next ring out takes 8 electrons to be "filled", the next ring 18, and the outer ring of any atom is filled when it has 8 electrons.



COPPER ATOM

rea that erial h a wh ave e th outer shell electrons tend to be insulators, or poor conductors, is that it would take less than 4 electrons added to the outer ring to achieve that "super stable" condition of 8 electrons in the outer ring . . . therefore the atomic "forces" tenaciously hold these **valence** (outer ring) electrons in their orbit . . . desiring to fill this ring, rather than "give up" electrons. This means that these outer shell electrons are hard to move from the atom. For atoms with less than 4 valence electrons, it turns out that the outer ring electrons can be removed from the atom with relatively little outside force or energy . . . and therefore these electrons are called **free electrons**, implying this condition. **Materials which have free electrons are conductors.** Copper, Gold, Silver, Lead, and many other metals fall into the category of **conductors**. Refer back to the sketch of the copper atom and note that there is only 1 valence (outer shell) electron. It would take 7 additional electrols to "fill" this ring and make this an electrically stable atom. This outer shell electron therefore can be "moved" easily . . . and since electrical current consists of an orderly progression (or movement) of electrons, it is quite easy to cause electrical current to "flow" in copper. As you might expect, semiconductors are neither good conductors, nor good insulators . . . and their outer shell consists of 4 electrons. Examples of semiconductor materials are: germanium and silicon.

Let's try another checkpoint to see if you have picked up the key facts regarding atomic structure, conductors and insulators.

CHECKPOINT

Electrons which are in the outer ring of an atom's structure are sometimes called _____ electrons.

If the atomic structure of a material is such that there are less than 4 electrons in its outer ring, the material is generally considered a _____. If there are more than 4 outer ring electrons, the material may be classed as an _____; and if exactly 4 electrons appear in the outer shell, the material is a _____.

Electrical "current" consists of an orderly progression of _____.

Copper, Gold, Silver and Lead would all be examples of? (conductors, insulators, semiconductors) _____.
Germanium and Silicon would be classed as? (conductors, insulators, semiconductors) _____.

Glass, rubber, and most plastics would be examples of? (conductors, insulators, semiconductors) _____.

ANSWERS:

Electrons which are in the outer ring of an atom's structure are sometimes called **(valence)** electrons.

If the atomic structure of a material is such that there are less than 4 electrons in its outer ring, the material is generally considered a **(conductor)**. If there are more than 4 outer ring electrons, the material may be classed as an **(insulator)**; and if exactly 4 electrons appear in the outer shell, the material is a **(semiconductor)**.

Electrical "current" consists of an orderly progression of **(electrons)**.

Copper, Gold, Silver, and Lead would be examples of **(conductors)**.

Germanium and Silicon would be classed as **(semiconductors)**. Glass, rubber, and most plastics would be examples of **(insulators)**.

Just in case you need some clarification . . .

a conductor is a material that allows electrical "current" to flow easily (has many free electrons and a low resistance to current flow)

an insulator is a material which shows a high resistance to electrical current

a semiconductor is a material which has a resistance to electrical current which is neither real low, like the conductor, nor real high, like the insulator.

INFORMATION

Now, let's amplify and explain the terms **resistance** and **current,** and at the same time throw in one more important electrical term, **electromotive force**, abbreviated **emf.**

We have already stated that **an electrical current is an organized, progressive movement or "flow" of electrons.** As you might guess, in an electrical circuit it is possible to cause "electron flow", or current to flow through the circuit by applying force, or energy which can cause the "free" electrons to move from atom to atom through the material. Also, as you might suspect . . . the lower the **resistance** of the circuit, the more electrons will be moved by a given force . . . in this case, **electromotive force (emf.)**

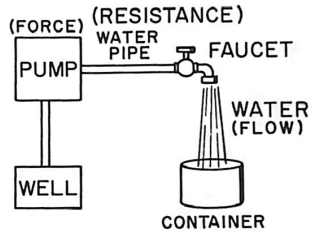
These three electrical quantities or **parameters** are of utmost importance in discussing electrical circuits. YOU MUST LEARN THESE, and the laws of electrical circuits related to them in order to obtain meaningful knowledge of electronics and Ham Radio, so let's discuss these terms, a little more fully.

EMF might be considered similar to pressure in a water system. Notice in the diagram, the source of water pressure is the pump. In the electrical circuit we'll discuss, the source of electrical pressure will be the battery. Just as water pressure has units of measure . . . "pounds of pressure", electrical pressure, or emf, has a unit of measure called the **volt.** Just as the amount of water "moved" by the pressure can be measured in gallons per minute, the amount of electrical current through the electrical circuit can be measured in **amperes** (number of electrons moved past a given point in a unit of time). (An ampere = 6.28 x 10^{18} electrons past a given point in one second).

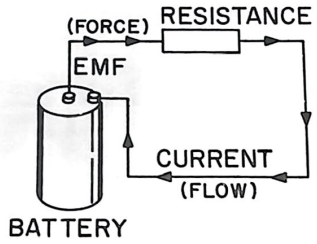
In the "water circuit", the smaller the water pipes, the more resistance they offer to the flow of water, and therefore, the less water will flow, per unit time, with any given water pressure. In the electrical circuit, the higher the **resistance** (that is, electrical resistance) of the circuit . . . the less the current (in amperes) that will flow for any given emf (or **voltage**). This relationship of **current** (electron flow), **voltage** (emf) and **resistance** was studied by a scientist named George Simon Ohm and he set forth these relationships in the now famous **OHM'S LAW**, which we will discuss shortly. First, though, review the concepts we've been talking about by carefully studying the illustrations in the adjacent column.

Try this checkpoint to make sure you're getting the idea.

REFERENCE & DATA



WATER "CIRCUIT"



ELECTRICAL CIRCUIT

CHECKPOINTS

CHECKPOINT

Electrical pressure is called _____ _____, abbreviated _____. The unit of measure for this electrical quantity is the _____.

Electrical current consists of the flow of _____ through an electrical circuit. The amount of current is determined by the number of _____ flowing past a given point in the circuit in a unit of time. The basic unit of measure of electrical current flow is the _____. A current of 1 _____ indicates a flow of 6.28 x 10^{18} electrons flowing past a given point in the circuit in a time of _____.

ANSWERS:

Electrical pressure is called **(electromotive force)**, abbreviated **(emf)**. The unit of measure for this electrical quantity is the **(volt)**.

Electrical current consists of the flow of **(electrons)** through an electrical circuit. The amount of current is determined by the number of **(electrons)** flowing past a given point in the circuit in a unit of time. The basic unit of measure of electrical current flow is the **(ampere)**. A current of 1 **(ampere)** indicates a flow of 6.28 x 10^{18} electrons flowing past a given point in the circuit in a time of **(one second)**.

We mentioned a few minutes ago that one source of electromotive force was the battery (or cell). Chemical "energy" moves the electrical charges in the materials used in the battery so that one terminal has an excess of electrons, and therefore is the negative terminal. The other terminal has a deficiency of electrons . . . or, if you prefer, an excess of protons, and is therefore the positive terminal of the battery or cell. Whenever this condition exists, we can say there is a **potential difference** between the two terminals. In other words, there is the potential to do the electrical work of moving electrons through a circuit . . . if a complete path or circuit for the electrons is provided between the terminals. This **potential**, or **potential difference** is the electromotive force we talked about earlier. It is measured in **volts**. For example, the average flashlight cell provides a potential difference between its positive and negative terminals of 1.5 volts. The emf, then, is 1.5 volts.

Now, what determines how many electrons can be moved through an electrical circuit if we apply that 1.5 volts of emf? As you might anticipate . . . the amount of electrical resistance the circuit has, is what **limits** the amount of current that will flow for any given emf "applied" to the circuit.

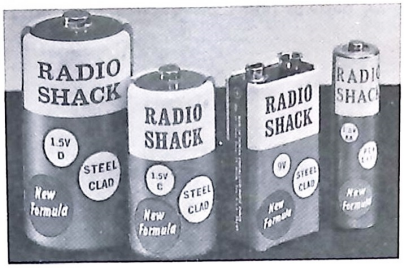
The unit of electrical resistance is the **OHM** . . . named in honor of George Simon Ohm, whom we mentioned earlier.

An **ohm** of resistance may be defined as that amount of resistance which will limit the circuit current to one ampere when one volt of emf is applied. Using this definition as a springboard, we can say that one volt is the amount of emf which will cause one ampere of current to flow through one ohm of resistance. Remember, we already defined one ampere of current flow as being 6.28 x 10^{18} electrons flowing past a given point in one second.

Remember, we talked about various materials being good conductors, poor conductors (or insulators) and semiconductors. A good conductor has low electrical resistance to current flow . . . and insulator has very **high** resistance to current flow . . . and a semiconductor has a resistance that is somewhere between the two extremes.

One of the most important components used in electrical circuits and electronics is the **RESISTOR**. This is a component that is made with a mixture of substances so the manufacturer can control the amount of resistance the **resistor** shows between its terminals. Since electronics is, in effect, the science of controlling electrons . . . this component is a very important device in electronics. We will study in more detail the various types of resistors later. Right now, we want you to learn the symbol used to show resistors in electrical and electronic "schematic diagrams" . . . which are simply the technician's shorthand method of symbolically representing electrical circuits. NOTE: It does not matter what value of resistance (in ohms) the resistor is . . . the symbol for all "fixed resistors" is the one shown in the next column.

Try the checkpoint!



BETTMANN ARCHIVE, INC.

GEORGE SIMON OHM

RESISTOR SYMBOL

CHECKPOINT

1. The resistance of a conductor is: (low, high)? _____.
2. The resistance of an insulator is: (low, high)? _____.
3. The unit of resistance is called the _____.
4. True or False? All fixed resistors use the same electrical symbol. _____
5. "Potential difference" between two points is measured in _____.
6. The terminal of a "voltage source" where there is an excess of electrons would be called the _____ terminal of the source.
7. One ohm of resistance will limit the current through an electrical circuit to one ampere of current when one _____ of emf is applied.
8. The unit of current is the _____.
9. The unit of emf is the _____.
10. The ohm is the unit of _____.

ANSWERS:

1. The resistance of a conductor is: **low.**
2. The resistance of an insulator is: **high.**
3. The unit of resistance is called the **(ohm).**
4. All fixed resistors used the same electrical symbol. **(true).**
5. Potential difference between two points is measured in **(volts).**
6. The terminal of a "voltage source" where there is an excess of electrons would be called the **(negative)** terminal of the source.
7. One ohm of resistance will limit the current through an electrical circuit to one ampere of current when one **(volt)** of emf is applied.
8. The unit of current is the **(ampere).**
9. The unit of emf is the **(volt).**
10. The ohm is the unit of **(resistance).**

How did you fare? Learn these terms well, for they are important!

O.K. Let's begin to see how these three important electrical **parameters** *are related by learning OHM'S LAW!*

By experimentation in his laboratory, Mr. Ohm was able to define the interrelationships of the three electrical quantities we have been talking about.

As logic would tell us, he discovered that the amount of current through an electrical circuit was directly related to voltage . . . which means, for a given resistance circuit, the higher the applied emf, or voltage . . . the higher the current, in amperes.

He also noted that current in an electrical circuit is **inversely** *related to the resistance . . . which means, for a given emf applied to the circuit, the higher the resistance . . . the lower the current. This certainly makes sense, for when you think of emf as a force which is trying to move electrons (current) through a circuit against some electrical resistance . . . it is obvious . . . the higher the resistance . . . the less the number of electrons moved with a given force applied. Stating the above in formula form, we have the relationships shown in the next column.*

Let's restate that formula using the standard abbreviations . . . or "shorthand" letters used to represent these terms.

The shorthand way of writing emf is **E**

The shorthand way of writing current is **I**

The shorthand way of writing resistance is **R**

If it will help . . . think of E for **e**mf; I for **i**ntensity of electron flow (or current) . . . and R for **r**esistance. Using these abbreviations, the basic statement showing the relationships of I, E and R is shown in the next column.

$$\textbf{Current (in amps)} = \frac{\textbf{Voltage (volts)}}{\textbf{Resistance (ohms)}}$$

I (in amperes) = **E** (in volts) divided by **R** (in ohms)

or

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{R}}$$

This formula is of tremendous importance . . . so learn it well!

From this basic formula, we can derive two other forms which are equally important to UNDERSTAND and learn. We won't take time here to explain the step-by-step derivation, but simply want you to understand the relatio ships of these electrical quantities.

Before we show you the other two forms though, look at our original formula again. We said earlier that current **(I)** was directly related to voltage **(E)** and inversely related to resistance **(R)**. You can see, for example, if we subsititute some values in the formula, this is true. If E were 10 volts, and R were 10 ohms . . . what would be the circuit current? Follow the steps in the next column.

$$I = \frac{E}{R}$$

$$I = \frac{10v}{10 \text{ ohms}}$$

$$I = 1 \text{ ampere}$$

Now let's suppose we doubled the voltage, but did not change the resistance in the circuit . . . what would be the current for this case? Again, follow the steps in the next column.

$$I = \frac{E}{R}$$

$$I = \frac{20v}{10 \text{ ohms}}$$

$$I = 2 \text{ amperes}$$

See! Doubling the voltage doubled the current . . . showing that current is directly proportional to voltage.

Now suppose that we keep the voltage at 20 volts (v), but double the resistance . . . what happens to current? Look in the 2nd column again.

$$I = \frac{E}{R}$$

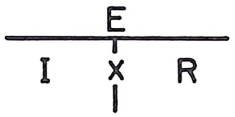
$$I = \frac{20v}{20 \text{ ohms}}$$

$$I = 1 \text{ ampere}$$

Note that with an emf of 20 volts, when we increased R to 20 ohms the current decreased from 2 amperes (abbreviated amps. or A) to 1 amp. As R doubled . . . I halved. This is the inverse relationship we mentioned.

From this basic formula of I = E/R. let's show you the two other forms of Ohm's Law which you will frequently use.

It can be shown that if I = E/R; then E = I x R . . . and R= E/I. To help you remember these three forms . . . study the "crutch" shown in the next column.



Notice that if you "cover" the quantity you are solving for . . . the physical position of the other two tell what to do with them.

Example: If I want to solve for E, simply read I x R. If I want to solve for I . . . then note that it's E over R (or E divided by R). To find R . . . note that E is over I (or E is divided by I). Handy little crutch, huh? Let's say again, however, it is far more important that you **understand** the concepts that make the formula true, than to purely memorize formulas without having a "foggy notion" as to why they state what they do.

How about a checkpoint here to let you practice using the important Ohm's Law formula?

CHECKPOINT

1. If an electrical circuit has 2.5 volts applied voltage and a resistance of 5 ohms . . . what will be the circuit current?
   Current = _____ amperes.
2. If the current through a 10 ohm resistor is 2 amperes . . . what is the voltage across the resistor?
   Voltage = _____ volts.
3. If the current through a circuit is 3 amperes when the applied voltage is 10 volts . . . what is the circuit resistance?
   Resistance = _____ ohms.

ANSWERS:

1. Current = **(0.5)** amperes
2. Voltage = **(20)** volts
3. Resistance = **(3.333)** ohms

INFORMATION

O.K. You've used all three forms of the Ohm's Law formula now . . . but we want you to begin learning how to apply this knowledge in a practical way by giving you some problems using circuit "schematic diagrams" to convey information to you.

Before we do that, however, let's talk for just a minute about what "instruments" are used to measure the three important electrical parameters we've been discussing. The instruments used are really quite obvious:
To measure emf in volts use a **voltmeter.** For our purposes we will use the following symbol to represent a voltmeter "schematically":

To measure current in amperes, use an **ammeter.** For our purposes, we will use the following symbol to represent an ammeter "schematically":

Incidentally . . . many times we will be dealing in thousandths of an ampere rather than amperes. As we mentioned earlier . . . the metric "prefix" for one thousandth of a unit is "milli". Therefore, we use the term **milliampere** to indicate one thousandth of an ampere . . . and we abbreviate this **mA.**

The symbol we'll use to show a **millammeter** in a schematic diagram is:

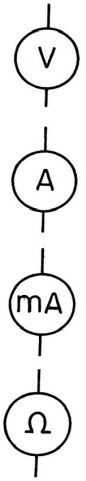
To measure resistance, an **ohmmeter** is used. We'll use the symbol:

While we're on the subject of resistance and **ohms** . . . we should point out that in many electronic circuits, we'll be dealing with thousands of ohms, and sometimes millions of ohms; and, again, you will find the metric prefixes come in handy. Remember that the term **kilo** means 1000. Our earlier example was that a kilometer is 1000 meters. Therefore, a **kilohm** is 1000 ohms. The common letter symbol, or abbreviation for kilo is **K**. Thus, if I am talking about a resistor which has 10,000 ohms of resistance, it would be general practice to say a **10K ohm** resistor. For designating millions, we use the prefix **Mega**. Hence, a 10 Meg (we leave off the a) resistor has 10 million ohms of resistance.

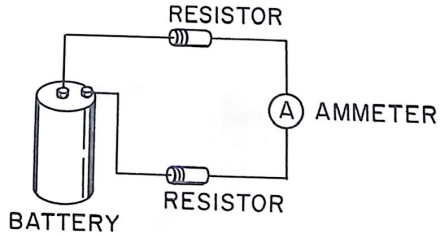
Now, let's get "down to brass tacks" in becoming familiar with schematic diagrams and using Ohm's Law to analyze these circuits.

Initially, let's define a circuit as being a voltage source and a complete path for electron flow from one terminal of the source to the other. Observe the diagram in the next column.

REFERENCE & DATA

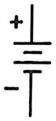


NOTE: The Greek letter **omega,** Ω, is often used to symbolize the word ohm (or ohms).



CHECKPOINTS

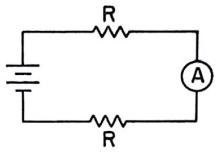
That was sort of a "pictorial" diagram. Let's learn the symbol for the battery, and then show you this same circuit in "schematic diagram" form. The symbol for a battery is:



A battery is really two or more cells internally interconnected. The symbol for a simple cell is:

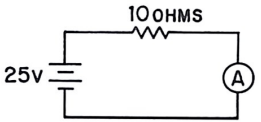
Please observe that the "short" line in the symbol represents the negative terminal of the cell, and the longer line the positive terminal. The same is true for the battery above . . . i.e. the short lines represent each cells' negative terminals; the longer lines the positive electrodes, or terminals.

Here's our schematic diagram for the circuit shown pictorially before.



We'll learn more about schematic diagrams when you get to the Technician and General Class study.

Look at the schematic in the next column, and by using Ohm's Law, solve for the circuit parameters asked for in the checkpoint in the third column.



CHECKPOINT

What will the ammeter read?
Current = _____ amperes.

ANSWER:
Current = **(2.5)** amperes.

Supposing that the resistance was 10K ohms instead of 10 ohms . . . then what would the current be? If you answered 2.5 mA (milliamperes) you would be correct.

All right! To see if you understand all three forms of the Ohm's Law formula, complete the checkpoint in column 3.

CHECKPOINT

1. If the resistance and voltage values for a circuit are known; what formula would you use to solve for the current?
   I =
2. If the voltage and current values are known for a circuit; what formula would you use to solve for the circuit resistance?
   R =
3. If the current and resistance values are known for a circuit; what formula would you use to solve for the circuit voltage?
   E =

ANSWERS:

1. $I = \frac{E}{R}$
2. $R = \frac{E}{I}$
3. $E = I \times R$

INFORMATION

Do you have those formulas well in mind? I hope so. You will use them the rest of your life as an Amateur or technician.

We've been speaking of moving electrons through a resistance by applying an electromotive force. As you can imagine . . . when this work is done, heat is generated. Even though we are talking about moving things as microscopic as electrons, heat is generated. In fact, a measure of how much work has been done in a given unit of time is called **power**. Electrical power is measured in units called **watts** . . . named in honor of the scientist who studied work, power and energy. For your purposes at this time, it is only necessary that you learn that the amount of power **dissipated** by a circuit (like we've been studying) is related to the three electrical quantities—E, I and R. For the time being, you'll only use one form of the power formulas, namely:

Try the checkpoint!

REFERENCE & DATA

P (power in watts) = **E** x **I**,
where E is in volts and I is in amperes.

CHECKPOINTS

CHECKPOINT

If a transmitter circuit has an applied voltage of 100 volts and a circuit current of 0.75 amperes . . . what is the power "input" to the stage?

P = _____ watts.

ANSWER:
P = E x I
P = 100 x 0.75
P = **(75)** watts

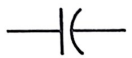
We have been dealing with some "pretty heavy" electronics fundamentals so far in this chapter. We felt that it was important to begin to lay the "ground-work" and give you a good "foundation" upon which to build in later chapters. Because the Novice Class License test does not require "in depth" electronic theory knowledge, we'll just introduce you to terms and rules and regulations which you may encounter in the Novice Class examination. In other words, we will not go into detailed explanation at this time, but simply will familiarize you with them for "exam" purposes. Later in the book, many of these topics will be taken up in detail.

Most all electronic circuits are made up of a combination of some, if not all, of the following six basic electronic components: Resistors, Capacitors, Inductors, Tubes, Transistors and Semiconductor Diodes.

You should learn the symbols for these, and some of their basic functions. Let's go through the list, one at a time.

The **resistor** is used to limit current, and in some cases to provide a desired **voltage drop** across itself. You have already seen pictures of resistors and the proper schematic symbol, so let's move on to the Capacitor.

The symbol for a **Capacitor** is:



The basic function of a capacitor is to **store** electrical energy. It does this by storing a **charge** so that one plate or set of plates of the capacitor has an excess of electrons, the other plate, or set of plates, a deficiency of electrons. As you can anticipate, once the capacitor is **charged**, it can act as a source of voltage and/or current until the charge is drained off. This draining of the charge is called **discharging the capacitor**. Notice the picture of several types of capacitors in the next column.

The more charge a capacitor can store for a given voltage applied, the higher its **capacitance**. The unit of capacitance is the **farad**. A Farad is that amount of capacitance which with one volt applied will store one **coulomb** (6.28×10^{18} electrons) of charge.

Try the checkpoint!

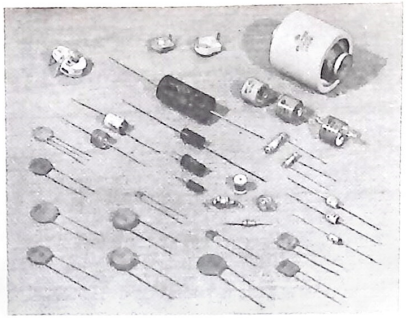


Photo courtesy of Centralab, the Electronics Division of Globe—Union, Inc.

CHECKPOINT

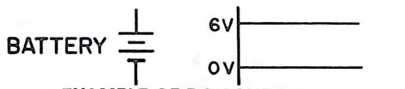
1. A resistor "limits" current and "drops" _____.
2. The unit of resistance is the _____, and the symbol for a resistor is:
3. The function of a capacitor is to _____ electrical energy in the form of a charge.
4. The unit of capacitance is the _____ and the symbol for capacitor is:
5. "Charge" is measured in "_____".

ANSWERS:

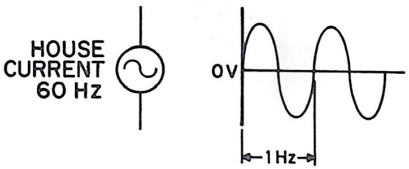
1. A resistor "limits" current and "drops" **(voltage)**.
2. The unit of resistance is the **(ohm)** and the symbol for a resistor is:
3. The function of a capacitor is to **(store)** electrical energy in the form of a charge.
4. The unit of capacitance is the **(Farad)**, and the symbol for a capacitor is:
5. "Charge" is measured in **("Coulombs")**.

Another function of a capacitor which you will learn more about later, is to block, or prevent DC (direct current) voltage or current from getting from one point in a circuit to another . . . and to allow, or pass AC (alternating current) voltages or current to pass from one point in a circuit to another.

So, summarizing the function of a capacitor: it stores electrical energy, and releases it in accordance with the circuit design; and it can be used to "block" DC and "pass" AC signals.



EXAMPLE OF DC SOURCE



EXAMPLE OF AC SOURCE

INFORMATION

The next component on our list is the **Inductor**, sometimes called a coil. The capacitor stores electrical energy in its "electric" field between plates of the capacitor. The inductor also stores energy in a field . . . but the inductor stores energy in the form of a "magnetic field", which we'll learn more about later.

Whereas the capacitor has the characteristic of "blocking" DC, and "passing" AC with little opposition . . . the inductor, or coil does just about the opposite. This means the coil allows DC to pass with little opposition, but tends to offer opposition to the passage of AC. In fact, the higher the "frequency" of the alternating current . . . the more the opposition to its passage through the inductor. You do remember our "old friend" frequency don't you? Recall that "house current" is probably at a frequency of 60 Hertz . . . and it is, of course, alternating current . . . abbreviated AC.

There are two basic types of coils that you need to know the symbols for: namely, the "air core" type . . . a coil wrapped around a form with nothing but air in the middle . . . and the iron-core type. Note the pictures of these in the next column.

The symbol for the air-core coil is:

The symbol for the iron-core coil is:

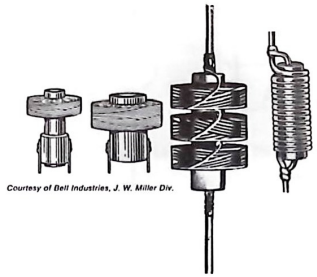
The unit of inductance is the ***henry****, named in honor of another scientist.*

Iron-core inductors are used in circuits which are operating at relatively low AC frequencies. For example, at power line frequency (60 Hz) up through what is called "audio" frequencies (from about 20 Hz - 20 kHz).

Air-core inductors are used at higher frequencies . . . often called ***RF*** *(radio frequency). Many circuits in your TV set may use these RF coils. Almost all electronic equipment requires power supplies of various sorts, where Iron-core inductors are used frequently. So, you see, inductors are very important electronics component.*

Verify your learning by doing the checkpoint.

REFERENCE & DATA



Courtesy of Bell Industries, J. W. Miller Div.

CHECKPOINTS

CHECKPOINT

1. A capacitor tends to block _____ but to pass _____ signals.
2. An inductor tends to allow _____ to pass with little opposition, but to impede _____ signals. The higher the frequency of signal, the (greater, smaller) _____ will be the inductor's opposition to its passage.
3. The unit of capacitance is the _____ .
4. The unit of inductance is the _____ .
5. The schematic symbol for a capacitor is:

6. The schematic symbol for an air-core inductor is:

7. The schematic symbol for an iron-core inductor is:

ANSWERS:

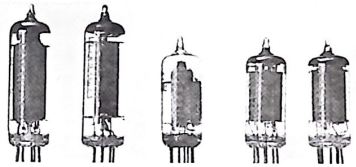
1. A capacitor tends to block **(DC)**, but to pass **(AC)** signals.
2. An inductor tends to allow **(DC)** to pass with little opposition, but to impede **(AC)** signals. The higher the frequency of the signal, the **(greater)** will be the inductor's opposition to its passage.
3. The unit of capacitance is the **(Farad)**.
4. The unit of inductance is the **(Henry)**.
5. The schematic symbol for a capacitor is:

6. The schematic symbol for an air-core inductor is:

7. The schematic symbol for an iron-core inductor is:

Trust you did well on that checkpoint. If you are are picking up all these new terms . . . you are getting a tremendous head start toward your more advanced classes of Amateur licenses, as well as being well prepared for the Novice test. Congratulations on your efforts so far. Keep up the good work. Near the end of this chapter, we will give you a review list of terms to help you.

The next item on our "grocery list" of six basic electonic components is the **Vacuum Tube**. We are not going to take time in this chapter to go into the theory of operation of all the various types of vacuum tubes . . . but simply want to introduce you to the general functions they are frequently assigned to perform in electronics circuitry . . . and perhaps a symbol or two.



The term "vacuum" tube implies that the tube's elements are in an "evacuated" enclosure (little or no "air" inside). Just as the light bulbs in your house are constructed with a "filament" inside an "empty" (no air) glass enclosure . . . so the vacuum tube has its electrical elements in an evacuated enclosure. Usually this enclosure is glass; or sometimes metal. Look at the picture of some vacuum tubes in the next column.

In electronics, vacuum tubes frequently perform one of the following functions:

They **rectify** signals
They **amplify** signals
They **generate** signals

INFORMATION

Now, what do those terms mean? For the time being, let's give you a brief definition of each function.

A **rectifier** changes AC voltages or currents to DC voltage or current. One example of the need for "rectification" is your radio or TV. If there weren't a rectifier and filter circuit in the power supply, you'd hear terrible 60 Hertz hum all the time. In a very simple statement . . . **a rectifier changes AC to DC.**

To **amplify** means to make larger or build up. A tube used to amplify simply builds up an **input** signal to a larger **output** signal. For example, one might put in a signal to an amplifier that is only 1 volt . . . but the "amplified" output voltage could be 100 volts . . . etc.

When a tube is used to **generate** an AC signal, it is often called an **Oscillator.** The tube's function here can simply be stated as changing the DC voltages into an AC signal of desired frequency—this becomes the output.

Most vacuum tubes have a **filament** . . . called a **heater.** The heater is used to heat up a tube element called the **cathode.** The job of the cathode is to "emit" electrons when it is heated. These electrons are then available to be "collected" by the tube's **plate.** The plate is the tube element which attracts the electrons which have been emitted by the cathode. The tube we have just described is called the **Diode** tube, because it has two active elements . . . the cathode . . . which emits electrons, and the plate . . . which collects them. The prefix "di" means two. For example . . . when you "disect" something, you cut it into two parts.

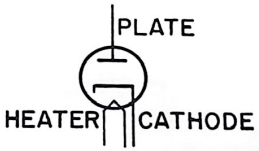
Look at the schematic symbol for the tube we have described is in the next column.

We've mentioned several functions of vacuum tubes as being rectification, amplification and their use as oscillators. The **diode** tube we just discussed often finds application as a **rectifier.** We will discuss how this is accomplished later in the book.

A tremendous "giant-step" forward was made in the world of electronics when Dr. Lee DeForest introduced a third major element in the vacuum tube. This element was physically placed between the cathode and the plate, and this third element was called the **control-grid.** Instead of being a solid piece of metal, such as the cathode or plate, the control grid has evolved to be a thin "spiral" of wire.

Because the tube now had three active elements, it became known as the **Triode** tube. The prefix **tri** means 3. Many examples of this prefix being used to designate 3 are available, but perhaps a very common one would be the common toy the "tricycle", which has three wheels.

REFERENCE & DATA



DIODE TUBE

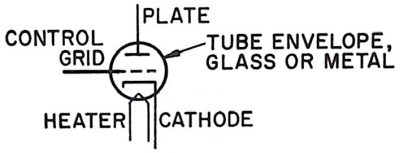
Dr. Lee DeForest

CHECKPOINTS

The symbol for the Triode tube is shown at the right. Remember, the cathode "emits" electrons, and the plate "collects" them. The control grid can control how many of the electrons will reach the plate . . . hence the term "control" grid.

Virtually all electronic vacuum tubes operate from the basic principles used in the diode and triode tubes. The addition of the control grid now made possible **amplification**. Amplification of a signal simply means that at the output of the amplifier stage or stages, the signal is many times greater in amplitude (voltage or current-wise) than the signal into the amplifier.

Let's pause for a checkpoint to see if you've learned some of these new terms and facts.



TRIODE TUBE SYMBOL

CHECKPOINT

1. What electronic application does the diode tube often have? Diodes are often used as _____.

2. Draw the symbol for a vacuum-tube diode. Include the heater. Label all elements.

3. What type of tube is often used as an amplifier? A _____ tube.

4. How many active elements does a triode have? _____.

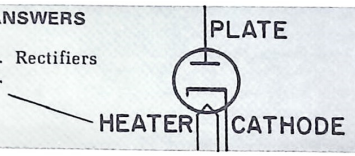
5. Draw the symbol for a vacuum-tube triode and label all the elements.

6. What is the basic function of the cathode in a vacuum tube? _____

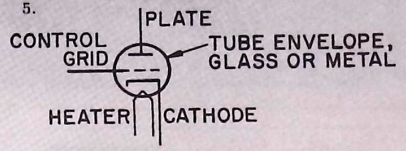
7. What is the basic function of the control-grid in a triode vacuum tube?

8. What is the function of the plate in a vacuum tube?

ANSWERS

1. Rectifiers
2. 

3. Triode
4. Three
5.



6. To emit electrons
7. To control how many of the emitted electrons reach the plate.
8. To "collect" the emitted electrons.

You may have noticed that we have changed our style in giving the answers. This is to conserve space and allow us to give you more teaching in a given space.

Now that you have had a chance to get used to the format of the book, you can see how to easily refer back to the **CHECKPOINTS** when checking your **Answers**.

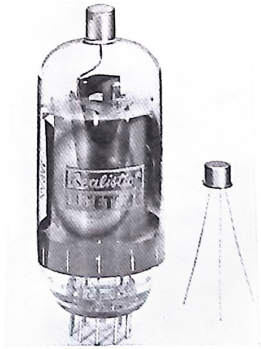
In the General Class section, we will expand on the vacuum tube, and discuss some other tubes that have been derived from the basic diodes and triodes. For now, we need to move ahead and briefly mention the device which has revolutionized the electronics industry . . . the **transistor.**

One of the tremendous advantages of the transistor is its small size. Also, because it doesn't need "heater" power, the associated circuitry is less bulky. Because of the low power requirements to operate transistors, most all the associated components have also been "miniaturized".

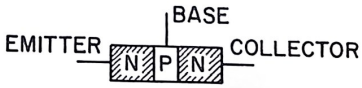
Transistors are frequently referred to as **semiconductors**, and as ***solid-state*** devices. They are called semiconductors because they are made of materials that "atomically" fall into the semiconductor category. The two most popular semiconductor materials for transistors are: **germanium** and **silicon**.

Both of these semiconductor materials have **four** "valence" electrons. (Remember our discussion of conductors, insulators, and semiconductors?) They are called solid-state devices because the various materials that make the active part of the transistor are all in one solid piece, as opposed to vacuum tubes, where the various elements are separated by space, etc.

For now, you should learn the symbols for the two basic types of transistors, and briefly, what is meant by "N" type material, and "P" type material.



Transistors vs Tube (size comparison)



Pictorial Concept of Transistor Materials "Sandwich" for "NPN" Transistor

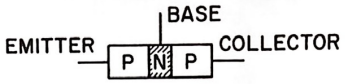
Note the symbols for the NPN and the PNP transistors. NPN simply means the **emitter** is N type material, the **base** is P type material and the **collector** is N type material. PNP would refer to a transistor with the opposite configuration, that is: **emitter** = P type; **base** = N type; and **collector** = P type materials.

Now, what in the world do we mean by N type material and P type material. Well, in a nutshell, N type is semiconductor material in which the manufacturer has purposely introduced some "special impurity" material which will cause it to have some relatively "free-to-move" electrons. Since electrons are negative, the term **N-type** was adopted for this material.

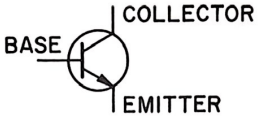
P type material is semiconductor material into which "special impurity material" has been integrated which has the characteristic of having less than 4 valence electrons in each atom (namely, 3), which causes the composite material to have some spots where electrons are lacking. These "pockets" or "holes" where electrons are lacking are considered positively charged (compared to what they would be if the electrons were there) . . . hence, **P-type** material became the name for this situation.

You will study later in the "General" chapter more about the function of the transistor elements: emitter, base and collector. For now, learn the symbols and the idea of N and P materials.

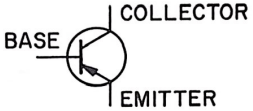
Let's see how you're doing. Give the checkpoint a try.



Pictorial Concept of "PNP" Transistor



NPN Transistor Symbol (Note: Emitter arrow points away from Base)



PNP Transistor Symbol (Note: Emitter arrow points toward Base)

CHECKPOINT

1. Name two advantages of the transistor compared to the vacuum tube.

   _____

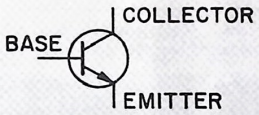
   _____

2. Draw the symbol for an NPN type transistor, and label the emitter, base, and collector leads.

3. Material in which an impurity has been injected so that there will be some electrons freed to move through the material is called _____ type semiconductor material.

4. A "hole" in an atomic structure may be considered as having a (negative, positive) _____ charge compared to what it would be were there an electron present.

ANSWERS:

1. Size, Lower power requirements. (Also, less fragile than tubes)
2. 

3. N type
4. Positive

INFORMATION

Two other transistor terms you ought to know (but don't need to know the "theory"): **Alpha** and **Beta**. Transistors have the capability of amplification, as many tubes do. These terms Alpha and Beta are used to indicate the amount of "gain" a transistor has. **Alpha** is simply the comparison of the "collector" current to the "emitter" current. The value of alpha for most transistors ranges between 0.95 and 0.99.

Beta, on the other hand, is the relationship of the collector current to the base current. The value of beta for transistors can range from 10 or 20 up to many hundreds. Beta is a very meaningful term for the design engineer, and is term that you ought to at least have heard.

Checkpoint!

REFERENCE & DATA

CHECKPOINTS

CHECKPOINT

1. The ratio of collector current to emitter current is called the transistor's_____.

2. The ratio of the collector current to the base current is called the transistor's_____.

ANSWERS:

1. Alpha
2. Beta

While we are on the subject of semiconductors, we should mention that semiconductor diodes have replaced many vacuum tube diodes in application. Just as you learned the symbol for the plate of the tube (collector of electrons emitted by the cathode), and the cathode (emitter of electrons), you should learn the symbol for the semiconductor diode. The ***anode*** *does the same job for this diode that the plate does in the tube . . . and the* ***cathode*** *basically performs the function of the cathode in the vacuum tube diode.*

Diodes, either semiconductor, or tube, perform quite a number of useful electronic functions. We've already mentioned **rectification** *(changing alternating current to direct current). Diodes also are used in receivers as* ***detectors****. You've heard the term AM radio. This refers to the method whereby the "intelligence" (sound) is put on the transmitted radio signal. A detector is often called a "demodulator", because the detector circuit (diode and several associated filter components) recovers the audio intelligence from the complex "modulated RF" signal, and sends this audio signal on to the audio amplifier circuitry in the receiver (to be built up to a level to drive a speaker or earphones).*

Another function that diodes are sometimes used for is to help "modulate" an RF wave . . . in other words . . . as a "modulator". Just learn the term for now.

Still other functions are electronic switching and limiting or clipping. (Limiting the amplitude of a signal . . . or clipping off part of the signal).

CATHODE ANODE

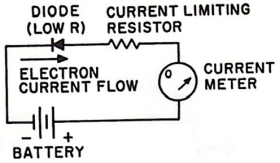
SEMICONDUCTOR DIODE

All these functions are derived from the fact that the diode will **conduct** (has a low resistance to current flow through it) when the anode is positive with respect to the cathode, and won't conduct (won't allow current to pass through it . . . or has a very high resistance) when the anode is not positive with respect to the cathode.

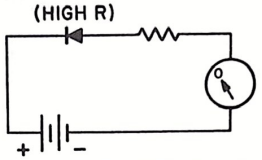
When the diode is in a condition of conducting . . . we say it is **forward-biased.** When the diode is in a condition of nonconduction, we say it is **reverse-biased.**

Recall that earlier we mentioned that capacitors and inductors could store energy, and release it when the circuit called for it. One very useful application of diodes combined with resistors, capacitors, and/or inductors is in power supply circuits. Since most electronic circuits require some DC operating voltages and currents . . . the diode(s) perform the job of changing the AC voltage from the power line to "pulsating DC". The FILTER components then "fill in the valleys" of the pulsating DC by releasing stored electrical energy at the appropriate times . . . and the output of the filter circuit then is "smooth" DC to feed the electronic circuits such as amplifiers, oscillators, etc.

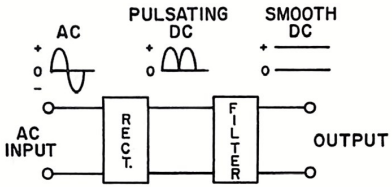
We'd better pause for another checkpoint, and see how you're doing.



FORWARD—BIASED DIODE



REVERSE—BIASED DIODE



RECTIFIER—FILTER SYSTEM
(Often called
"the power supply")

CHECKPOINT

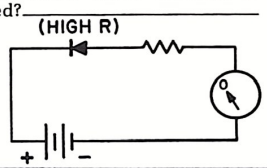
1. Draw the symbol for a semiconductor diode, and label the anode and cathode.

2. In order for the diode to "conduct", the anode must be more (positive, negative) _____ than the cathode.

3. Underline the functions listed below in which the diode may be used:
rectifier, amplifier, clipper, detector, demodulator, modulator, limiter.

4. The purpose of a power supply filter is to provide (smooth, pulsating) _____ _____ DC at its output.

5. Is the diode shown below forward or reverse biased?_____



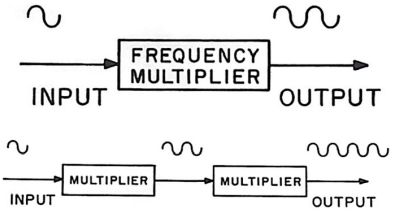
ANSWERS:

1.

2. Positive
3. Rectifier, clipper, detector, demodulator, modulator, and limiter should have been underlined.
4. Smooth
5. Reverse biased.

O.K., let's move on to some other terms that might appear on the FCC test. It is not neccessary at this time to know all the detailed theory for each term, but you should be aware of the basic concepts of each term.

In Amateur Radio and in Commercial Radio, many transmitters have stages referred to as **frequency multipliers** . . . or simply **multipliers**. The function of a multiplier stage is to produce some multiple of the input signal frequency at its output. (See the illustration). In a practical sense, multipliers may produce useable output at 2, 3, or 4 times the input signal frequency. Efficiency factors prevent a single stage of "multiplication of frequency" to go much above 4 times. If more multiplication is needed, the output of one multiplier stage is fed to another multiplier stage as required. Incidentally, a multiple of any given frequency is called a **harmonic**. For example, the 2nd harmonic of 100 Hz is 200 Hz; the 4th harmonic of 300 Hz is 1200 Hz . . . and so on.

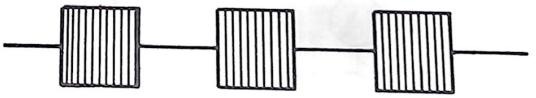


Another term related to transmitters is **parasitics**. You are probably familiar with the word parasite . . . referring to the animal kingdom. Generally, this refers to something attached to "whatever" and drains off part of the resources of the main object to sustain itself. In the transmitter . . . a **parasitic oscillation** is one which is not at the desired frequency . . . and is often far removed in frequency. To sustain this "undesired" parasitic . . . some of the stage's useful energy is used.

Still another transmitter term is the word **overmodulation**.

Think back a little and you will remember that we mentioned the term modulation. Transmitters accomplish the feat of putting the audio "intelligence" on the transmitted wave by one of several methods. AM signals are those using Amplitude changes for doing this . . . hence, **AM = Amplitude Modulation.** FM signals use either frequency changes or phase changes to perform this function. In any case, **overmodulation** refers to a transmitter signal in which the audio signal modulates the radio frequency signal MORE THAN 100%. When this happens . . . "spurious" (unwanted) new frequencies are generated . . . and the FCC frowns on this.

While on the subject of transmitters, let's quickly discuss what **A-1 transmission** means. This is the type transmission you will be using as a Novice Class operator. In essence . . . it is "amplitude-modulated telegraphy" without use of audio . . . in other words "on-off" keying of an RF carrier. The "A" shows that it is Amplitude modulation; whereas the 1 inciates telegraphy by "on-off" keying.



RF BURSTS (Keyed RF)
WITHOUT KEY CLICK FILTER

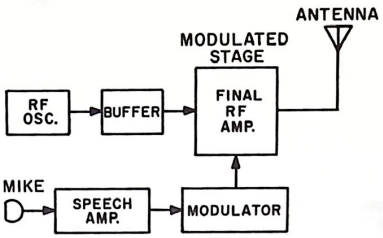
Another term you might see, which is related to keying, is the term **key-click filter**. The purpose of the key-click filter is to reduce radiation of undesired, or spurious frequencies, which can be caused when the RF signal is turned "on and off" abruptly. The filter, in essence, smooths the beginning and ending of each "pulse" to reduce this effect.

KEYED RF WITH FILTERING

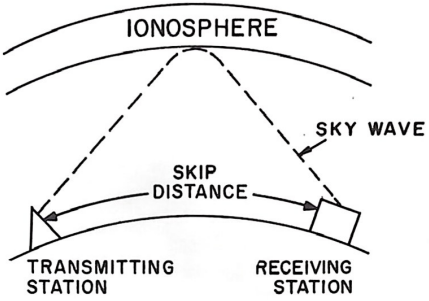
Still another term related to transmitters that you should know is **modulator**. The modulator is the stage of a transmitter which "puts" the audio intelligence into the appropriate "modulated-RF" stages so that the RF and the intelligence form one composite transmittable signal. The modulator can perform this function by varying the amplitude of the RF signal at the audio rate; or by varying the frequency or the phase of the RF at the audio rate.

While on the subject of transmitters, we might mention that most transmissions in the Amateur Radio bands depend upon the **sky-wave** mode for long-distance transmissions. Sky-waves are radio signals which are bent back toward earth by a layer of ionized space called the **ionosphere**. Note the figure showing the transmitted signal leaving the point of origin, traveling at an angle toward the heavens, then being bent back toward earth and being received a long distance from its point of origin. This is sometimes called **skip**. The conditions of the **ionosphere** vary from night to day, and in relation to the 11 year **sun-spot cycle**. This explains why it is possible to be hearing a radio amateur clearly at one time, and then not be able to hear him at all a few minutes or hours later.

We'd better pause for a couple of minutes, and give you a "True-False" checkpoint, since we've covered quite a bit of territory since the last checkpoint.



A TYPICAL AM TRANSMITTER SHOWING FUNCTION OF THE MODULATOR



CHECKPOINT

Answer T for true and F for false.

1. Frequency Multipliers can only multiply frequencies to some harmonic of its input frequency, and not to 1½, 2¼, etc. times. _____
2. The third harmonic of 150 Hz is 300 Hz _____
3. Parasitics are desired frequencies which are generated in certain transmitter stages. _____
4. When we say that a transmitter is "overmodulated", or, that overmodulation is occurring, we mean that the RF signal is being modulated more than 100%. _____
5. A key-click filter is used to quiet the sound of the key at the radio operator's desk. _____
6. A-1 transmission refers to radiotelephone transmissions. _____
7. A modulator is used mainly in amateur receivers. _____
8. A modulator changes AC to DC. _____
9. A sky-wave prevents "skip". _____
10. The sun-spot cycle is 11 years. _____

ANSWERS:

1. T
2. F (3rd Harmonic = 3 x 150 = 450 Hz)
3. F (Undersired signals)
4. T
5. F (Used to filter RF to prevent spurious frequencies . . . or to at least reduce them)
6. F (A-1 means radio**telegraphy**) Radio**telephone** refers to transmission of voice signals—"telegraphy" implies "code".
7. F (Used in transmitters)
8. F (Inserts audio into RF stage/s)
9. F (Enables skip)
10. T

INFORMATION

O.K., let's move on now and talk about some fairly common problems related to Amateur transmitters . . . and what precautions can be used to reduce or prevent them.

First, let's mention the term **chirp** as it related to c.w. (telegraph) transmissions. **Chirp** is a quick change in transmitter frequency which can occur as the transmission is keyed on and off. It is due usually to the oscillator being keyed, and sounds to the person at the receiving end of the transmission like a bird's chirping . . . hence the term "chirp". Common preventative measures include: Don't use a circuit which will key the oscillator (key a stage after the oscillator); use an oscillator with good frequency stability; use a stage between the oscillator and final transmitter stage (called a **buffer** stage).

Another problem in some transmitters is the **radiation of harmonic frequencies** (undesired). To help reduce this possibility, the following measures should be used: 1. Be sure final stage is being operated with proper electrical parameters. 2. The transmitter should be designed with tuned circuits which are selective. 3. Use a good coupling circuit between the final amplifier stage and the antenna. (One which has good frequency selectivity).

A third problem in transmitters for which YOU should be very aware is **SHOCK HAZARD**. Most transmitters use voltages and currents which can be lethal. It behooves any user of a transmitter to know SAFETY PRECAUTIONS you should use ANY TIME you operate or work on a transmitter. In fact, these precautions should be used when working with ANY type electrical equipment. Some of these precaution are:

1. Keep your body away from open electronic circuitry which is on. (Usually, good equipment has enclosures for this purpose).
2. Be sure equipment is properly grounded.
3. Be sure antenna lead-in wires, etc., are kept away from power lines.
4. Use equipment which has good design (Such as power supply **bleeder** resistors to discharge capacitors when equipment is turned off . . . etc.)
5. COMMON SENSE

When an Amateur "puts" a transmitter "on the air", he must be sure he knows what the transmitter output frequency is—to be sure he is "legal".

There are several methods of determining the operating frequency of a transmitter . . . but, basically they all involve comparing indirectly the transmitter frequency with broadcasts of the National Bureau of Standards stations. (WWV, WWVH, WWVB, etc).

REFERENCE & DATA

CHECKPOINTS

Some of the methods for this "indirect" comparison are:

1. Measure the transmitter frequency with a frequency meter, or a calibrated wave meter (which is frequently "calibrated" against the NBS transmissions, WWV, or other National Bureau of Standards stations).
2. Check with a receiver of known accuracy . . . again . . . one whose dial has been calibrated against the NBS broadcasts recently.

Note: The NBS broadcasts information shown in column 2.

All right! We've talked about several different concepts in the last few paragraphs . . . Time for a checkpoint!

The National Bureau of Standards maintains two radio transmitting stations: WWV in Colorado and WWVH in Hawaii. These two stations broadcast radio signals which are extremely accurate frequency standards. Sufficient for you to know that their accuracy far surpasses your ability to determine even a minute discrepancy. WWV operates on 2.5, 5, 10, 15, 20 and 25 MHz. WWVH operates on 5, 10 and 15 MHz.

Canada has a station (CHU) which transmits on precise frequencies of 3333, 7335 and 14,670 kHz.

CHECKPOINT

1. **Chirp** refers to a quick change in transmitter frequency which is generally caused by a transmitter_____ being the "keyed" stage.

2. True or False? One way of preventing "chirp" is to design the transmitter with a "buffer" stage._____

3. True or False? The coupling circuit between a transmitter's final output stage and the antenna should not be very selective in order to prevent unwanted harmonic frequency radiation._____.

4. True or False? Wave-meters, Frequency Meters and Receivers may all be used to help determine a transmitter's operating frequency._____

5. The final criteria for frequency determination for Amateurs are broadcasts from NBS station. True or False?_____.

6. Name several safety rules to help prevent the possibility of being shocked when working on electrical equipment:_____.

ANSWERS:

1. Oscillator
2. True
3. False (Should be selective)
4. True
5. True
6. Keep body away from equipment that is turned on.
   Be sure equipment is properly grounded.
   Keep lead-ins, etc. away from power lines.
   Use only equipment of good design.
   Use COMMON SENSE.

INFORMATION

Just before we leave the electronics portion of this chapter and proceed into the "Rules & Regulations" part . . . we need to teach you how to calculate the "input power" to a transmitter's final stage (the stage which sends the signal to the antenna). Since a Novice is limited to a maximum of 75 watts of input power to the "final stage"; you need to know how to determine what the input power is to YOUR transmitter's final stage.

Here's the simple procedure:

Power input = DC plate voltage (to the final tube/s) times the final stage plate current.

For example, if a transmitter final stage consists of two tubes in parallel, and: Their plate voltage = 450 volts, and each tube current is 50 mA . . . this means the total final plate current is 100 mA . . . therefore: Pin = 450 x 0.1 = 45 watts.
(Note: 100 mA = 0.1 amperes . . . remember the units and milliunits study earlier in the chapter?)

Now, you try one! Solve the checkpoint problem.

Did you do alright? In most transmitters, the plate voltage to the final stage is virtually the same as the transmitters's high voltage B+ supply . . . so don't let the term "B+" throw you.

O.K. Let's proceed to a section of the chapter where we will go somewhat against our basic philosophy of NOT MEMORIZING BUT UNDERSTANDING.

REFERENCE & DATA

Pin = E (plate) x I (plate)

CHECKPOINTS

CHECKPOINT

An amateur transmitter utilizes a B+ value of 500 volts which is fed to the plate of the final amplifier stage. The final stage is being operated at a plate current of 120 mA. What is the input power to the final stage of the transmitter? Use column 2 space for your calculations.

ANSWER:

Pin = E (plate) x I (plate)

Pin = 500 (volts) x 0.12 (amps)

Pinput = 60 watts

F.C.C. RULES AND REGULATIONS

When learning the F.C.C. "Rules and Regulations" regarding Amateur Radio . . . it is just about impossible to do it in any other way than "rote memory". So for this reason, we have "lumped" the rote memory learning necessary for the Novice test into this one section. The FCC test is sure to have many of these items included . . . so study them well.

Let's deal first with information regarding the transmitter and transmissions from a Novice station.

As mentioned earlier, the **maximum input power** permitted to the final stage of a transmitter operated by a Novice is 75 watts. In other words, the product of the final plate voltage and the final plate current must not exceed 75 watts.

Novice frequencies are limited to the following:

3700-3750 kHz (in the 80 Meter band)

7100-7150 kHz (in the 40 Meter band)

21.1-21.2 MHz (in the 15 Meter band)

28.1-28.2 MHz (in the 10 Meter band)

Regarding the purity and stability of emissions from all amateur transmitters, the FCC says essentially the following:

1. Must not interfere with receiving equipment (nearby) of good design.
2. Must be as stable as the "state of the art" will permit.
3. Voice modulation must not generate spurious signals.
4. Maximum modulation percentage = 100%
5. Simultaneous AM and FM modulation is NOT allowed.

Regarding the **control of the frequency** of a Novice transmitter, the FCC has made a fairly recent change. It is now allowable to use either "crystal control" of the transmitter frequency, or "variable-frequency-oscillator" (VFO) control. (The VFO must be of good design with good frequency stability).

A Novice Class licensee can ONLY operate his station in the "telegraphy" mode ("CW" or "code" **only**). He cannot use voice emissions when he is the prime operator.

Let's see what you've learned so far. Perform the checkpoint.

CHECKPOINT

1. Is a Novice operator who is operating his transmitter with a final plate voltage of 750 volts and a plate current of 100 mA. on a frequency of 21,250 kHz operating legally? _____
   EXPLAIN:
   _____
   _____
2. Can a Novice operate his station on "phone" (voice) if he clearly identifies himself as a Novice operator? _____
3. A Novice operator gets a complaint that he is interfering with his neighbor's TV set. Assuming the TV set is of reasonably good design . . . is the problem the neighbor's to solve, or the Novice operator?
   _____
4. Can a Novice use a VFO to control his transmitter's frequency? _____
5. When is it permissible to utilize a combination of FM and AM transmission from the same transmitter? _____

ANSWERS:

1. No. Explanation = O.K. on power input (it's 75 watts); but NOT O.K. on frequency of operation. Upper frequency limit for Novices on 15 meter band is 21,200 kHz (21.2 MHz).
2. No
3. Novice's problem
4. YES
5. NEVER

INFORMATION

REFERENCE & DATA

CHECKPOINTS

OPERATIONAL PROCEDURES

Moving ahead . . . let's consider some operational rules and regulations.

You should know that the maximum penalty for a violation of FCC rules and regulations is a fine of up to $500 for each day of the offense, suspension of operator license and revocation of the station license.

One of the infringements of rules and regulations would be the transmission of obsene or profane language. Also, transmission of false signals, or malicious interference are prohibited.

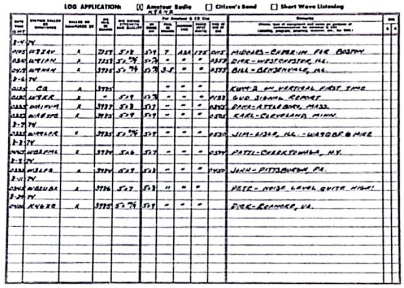
In regard to who may operate a transmitter licensed by a holder of the Novice Class license, the FCC says that any U.S. Amateur operator may do so. (**Licensed operator,** that is). There is a stipulation, however, if the operator operates other than within the limitation of the Novice Class license (let's say he's a General Class operator) . . . Both your station call letters **and** HIS must be used for identification purposes on the air.

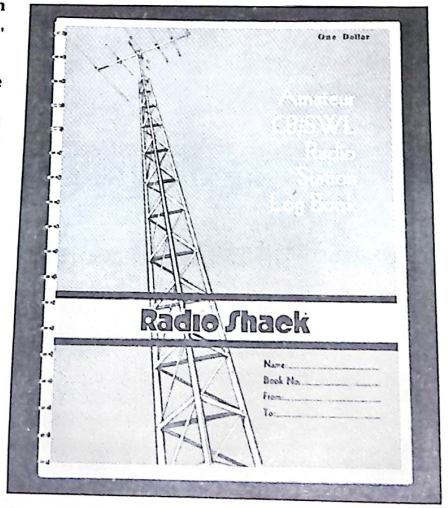
A very important document to all amateur operators is the **Station Log.** The "log" is the station's written record of transmissions, and should contain the following basic information:

1. Callsign of station and written signature of the licensee.
2. Signature of the control operator (and his callsign, if not the licensee).
3. Location of station. (If a "mobile" station operated within 100 miles of station address, use the term "local" . . . otherwise enter location for first and last transmission of the day.)
4. Input power
5. Type of emission (A-1 for Novice Class)
6. Frequency band used
7. Dates of operation
8. Information regarding any "3rd party" messages.
9. Time of starting and ending each given series of transmissions.

A Novice Class license is valid for two (2) years, and normally MAY NOT BE RENEWED. The exceptions are certain military servicemen cases, and one may take a new test and obtain a new Novice license 12 months after expiration of any FCC amateur license. Hopefully . . . you won't let your license expire, and you won't take two years before obtaining a higher than Novice Class license.

When operating an amateur radio station (of any Class), the FCC requires that you identify your station (by giving the call letters) a minimum of once each ten minutes. Also, when ending a transmission or series of transmissions, the callsign shall be given for the station with which you have been in contact.


LOG APPLICATION ☒ Amateur Radio ☐ Citizen's Band ☐ Short Wave Listening



Your Radio Shack store has a fine Log Book, especially designed for multiple use. It has some useful information at the beginning.

An answer to the question of whether you can communicate "with anyone in the world" is best summarized by the following information from Article 41 of the Radio Regulations Geneva Edition, 1968. It states that communications is prohibited between amateurs in different countries, if one of the countries objects to such communications.

Amateur messages in general are limited to:
1. messages of a technical nature.
2. messages of personal nature.

Ham radio should not handle messages which would normally be handled through commercial communications systems. In other words, you can not deprive Commercial communications systems of their income—**or you're in trouble.**

Also, it should be noted that communications on behalf of anyone other than the licensed amateurs is prohibited . . . unless the two countries involved have what is called a "third-party agreement". (The U.S. has such an agreement with 26 countries in the world).

O.K. Let's check up on operational regulations. Try the checkpoint!

CHECKPOINT

1. What is the maximum fine for violation of FCC rules and regulations?
   $_____ a day.
2. Is it all right to swear on Amateur radio?
   _____
3. Can a General Class operator use a Novice Class station?_____
4. The written document which records a station's operation is called the station _____ .
5. How long is a Novice Class license valid?
   _____
6. How often must you identify your station on the air? _____
7. Can you communicate with anyone in the world, if radio transmission conditions permit? _____ .

ANSWERS:

1. $500 a day (for each day of offenses)
2. NO
3. YES
4. Log
5. 2 years
6. At least once each ten minutes
7. No (not if one of the countries objects)

Now, let's finish our Rules and Regulations and Operation Procedures study with some miscellaneous facts you should learn.

You cannot hold a Novice **and** a Technician Class license at the same time.

The Novice Class license examination is available only by mail.

You can only take the Novice test under the supervision of an amateur holding a General Class license, or higher.

The Novice Class license does not allow credit toward a higher class license. To get a higher class license, it is necessary to meet all (code and written) requirements for the class attempted.

INFORMATION

When you want to operate an amateur station in the "portable", or "mobile" operation modes, you don't have to give written notice to the FCC "Engineer-in-charge" in your inspection district—unless you intend to operate in this manner for more than 15 days. In this case, you must give notification in writing to him.

There are antenna height restrictions on amateur stations, however, we will not go into detail on these at this time. You just need to know that height restrictions are to prevent the antenna from becoming a hazard to air navigation.

There are only certain specific situations where "one-way" amateur communication is allowed. These are:

1. emergency communications.
2. information bulletins consisting of subject matter of direct interest to amateurs . . . such as code practice transmissions, or "round-table" discussions involving more than two stations.

However, normally 2-way communications is expected by FCC.

Regarding the proper procedure for calling or answering other amateur stations, the following is an example:

1. Give callsign of station being called.
2. Follow this by word **"de"** (meaning "from")
3. Then give call sign of station transmitting.

Here's an example:

"W2XYZ W2XYZ de W4ABC $\overline{AR}$*."*

Whereupon W2XYZ answers . . .

"W4ABC de W2XYZ K."

This example means:

"W2XYZ W2XYZ from W4ABC
W4ABC end of transmission $(\overline{AR})$*"*

Whereupon W2XYZ answered:

"W4ABC from W2XYZ invitation to transmit (K)"

As you get on the air after getting your license, you will find that many abbreviations are used by telegraphy stations in order to conserve time. As a result, a series of "Q" signals has been developed which are commonly used by Amateurs. A few of the more common ones are listed below, and may be found on the FCC exam.

QRA? means-What is the name of your station?

QRM? means-Are you being interfered with?

QRN? means-Are you troubled by static?

QRS? means-Shall I send more slowly?

and **QRT?** means-Shall I stop sending?

Time for another Checkpoint!

CHECKPOINT

1. Is it necessary to go to the FCC office to take your Novice test? _____
2. Can you apply the 5 WPM code test that you passed to get a Novice test toward the Technician Class license? _____
3. If you plan to operate your station "portable" (at another location) for 17 days . . . is it necessary to contact the FCC office by mail? _____
4. What "Q" signal would you use to ask: "Are you being interfered with?

_____

ANSWERS:

1. NO (in fact you can't take the Novice test at the FCC office)
2. NO
3. YES (if operation is intended for more than 15 days . . . it is necessary)
4. QRM?

Trust you did all right on that.

It has been quite some time since we mentioned the word "code" to you. KEEP PRACTICING! Two words to the wise are sufficient.

We have given you a good deal of electronics information plus operational and regulatory information to study for the Novice test. Certainly, if you know all that has been covered you should be "in good shape" for the Novice test . . . however, may we recommend, just for insurance, that you obtain a copy of "The Radio Amateur's License Manual" published by the American Radio Relay League (your local library or bookstore should have it). Go through the "Novice License" chapter a couple times for reinforcement of the important facts.

INFORMATION

Also, to help you, we are now going to summarize in "distilled" form most of the important terms and formulas. This will make a good study of the electronics part of the Novice test in "Capsule form".

The rules and regulations will not be repeated here. . . so recycle yourself as required to get them down. Good luck!

REFERENCE & DATA

IMPORTANT TERMS:

EMF = electromotive force
Unit of measure is **volt**

I = current
Unit of measure is **ampere**

R = resistance
Unit of measure is **ohm**

P = power
Unit of measure is **watt**

Hertz = cycle
kHz = *kilohertz (1000 cycles)*
MHz = *megahertz (1,000,000 cycles)*

λ = *lamda (greek letter) meaning "wavelength" (in meters)*
f or F = *frequency (number of hertz per second)*
C.W. = *continuous wave (or code type transmission)*
RF = *radio frequency signal*
DC = *direct current*
AC = *alternating current*
Cycle = *one completed chain of events out of a series of repetitive recurring events*
Wavelength = *distance an electrical wave can travel during the time of one cycle (or Hertz).*
Atom = smallest particle of matter which contains the characteristics of the element
Electron = smallest particle of negative charge (revolving about nucleus)
Proton = a positively charged particle (contained in nucleus of an atom)
Neutron = neutral (electrically) particle
Valence Electrons = those in outer ring of atom

REFERENCE & DATA

Ion = atom which has lost or gained electrons
Conductor = material with many "free" electrons . . . and consequently has low electrical resistance to current flow.
Insulator = material with few "free" electrons . . . high resistance.
Semiconductor = material with 4 valence electrons per atom.
Resistor = component designed to limit current flow
Capacitor = component that stores electrical energy in form of an electric field
Inductor = component that stores electrical energy in form of an electromagnetic field
Milliammeter = electrical measuring device that measures "thousandths" of an ampere of current.
Ohmmeter = measuring device for measuring resistance
Voltmeter = measuring device for measuring emf
Henry = the unit of measure of inductance
Farad = the unit of measure of capacitance
Rectifier = device that changes AC to pulsating DC
Filter = device (circuit) that changes pulsating DC to smooth DC
Diode = a vacuum tube or semiconductor with two active elements
Cathode = emitter of electrons
Anode or Plate = collector of electrons
Control Grid = element in tube that controls flow of electrons from cathode to plate
Filament or Heater = part of a tube that heats the cathode to a temperature that will cause "emission" of electrons

REFERENCE & DATA

Amplifier = device to enlarge signals electronically
Oscillator = electronic device which generates an AC signal (when supplied with appropriate DC element voltages)
Triode = tube with three active elements
Transistor = three element "solid state" device
Emitter = element of transistor roughly similar to cathode
Base = element of transistor which helps control electron flow
Collector = element in transistor somewhat similar to plate in tube.
NPN = transistor where emitter and collector are made of "N" type semiconductor material and base is "P" type material.
PNP = transistor where emitter and collector are made of "P" type semiconductor material and base is "N" type material.
Alpha = ratio of collector current to emitter current in a transistor
Beta = ratio of collector current to base current in a transistor ("current gain" of transistor)
Frequency Multiplier = Stage that amplifies a signal and produces harmonics in its output, from which it selects a desired multiple of the input signal as its output.
Sky wave = RF transmission "bounced" off of ionosphere
Skip = distance between origination of sky wave signal and its reception point.
Harmonic = multiple of a given frequency
Log = document in which Amateur's keep record of transmissions, etc., of their radio station

Once you have learned the important terms just reviewed, it will be a good idea to review some of the important formulas shown in column 2.

All right! If you have reviewed the important formulas, the important terms, and have gone through the "Novice License" chapter of the ARRL License Manual . . . you are ready to try a sample FCC type written test.

The questions will be multiple choice, just as FCC tests are. We will give you a few more questions than you will have on the actual FCC Novice test . . . just for extra practice, and to be sure we've covered all the material well. The FCC tests will consist of just 20 questions . . .

Use the speical test sheet provided. We've given you an example of the question format. Indicate the answer you think BEST answers the question, or completes the statement.

Get the idea? O.K., try the "super-duper" checkpoint that we'll call "SAMPLE NOVICE TEST" and see if you're ready for the real thing. REMEMBER . . . mark your answers on the test sheet only, not on the checkpoint. When you're through, check yourself with the answer sheet at the back of the book—don't cheat now—you don't learn that way!

The FCC test will be in a slightly different format, but that won't bother you.

IMPORTANT FORMULAS:

Wavelength = $\frac{300{,}000{,}000}{\text{Frequency (in Hertz)}}$

or

$\frac{300}{\text{Freq (in MHz)}}$

1 MHz = 1,000 kHz = 1,000,000 Hertz

1 mA = one thousandth of an ampere

1 K ohm = one thousand ohms

EXAMPLE:

5. Who was buried in Grant's tomb?
a. General Grant
b. General Washington
c. General Lee
d. General Nuisance
e. None of the above

You would complete your test sheet by circling or checking statement A.

Current (in amperes) = EMF (in volts) divided by R (in ohms)

$I = \frac{E}{R}$

$E = I \times R$

$R = \frac{E}{I}$

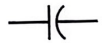
Power in watts = E (in volts) x I (in amperes)
$P = E \times I$

Final Amplifier "Input Power" = Final plate voltage x final plate current.
Pin = E plate x I plate

SAMPLE NOVICE TEST

1. The schematic symbol for an NPN transistor is:

a.

b. 

c.

d.

e.

2. A conductor has:

a. 8 outer ring electrons per atom
b. 4 outer ring electrons per atom
c. 0 outer ring electrons per atom
d. Many free electrons
e. High resistance

3. Ohm's Law states that:

a. $I = E \times R$
b. $R = I/E$
c. $I = E/R$
d. $R = I \times E$
e. $I = E + R$

4. To measure current, use a/an:

a. Voltmeter
b. Wattmeter
c. Ohmmeter
d. Watt-hour meter
e. Ammeter

5. The unit of capacitance is the:

a. Ohm
b. Henry
c. Farad
d. Beta
e. Hertz

6. An insulator is a:

a. Good conductor of electricity
b. Poor conductor of electricity
c. Material with many free electrons
d. Material with no electrons
e. None of the above

7. An "amplifier"

a. Changes AC to pulsating DC
b. Changes DC to AC
c. Increases the amplitude of a signal
d. Changes the frequency of a signal
e. Changes pulsating DC to smooth DC

8. An oscillator:

a. Changes AC to pulsating DC
b. Changes DC to AC
c. Increases the amplitude of a signal
d. Changes the frequency of a signal
e. Changes pulsating DC to smooth DC

9. A rectifier:

a. Changes AC to pulsating DC
b. Changes DC to AC
c. Increases the amplitude of a signal
d. Changes the frequency of a signal
e. Changes pulsating DC to smooth DC

10. A filter:

a. Changes AC to pulsating DC
b. Changes DC to AC
c. Increases the amplitude of a signal
d. Changes the frequency of a signal
e. Changes pulsating DC to smooth DC

11. A multiplier:

a. Changes AC to pulsating DC
b. Changes DC to AC
c. Increases the amplitude of a signal
d. Changes the frequency of a signal
e. Changes pulsating DC to smooth DC

12. A sky wave:

a. Is an RF signal that never returns to earth.
b. Is an RF signal that is reflected off the Ionosphere
c. Is an audio signal used to modulate
d. Is a DC wave
e. None of the above

13. A-1 Transmission means:

a. Radiotelephone
b. FM
c. AM telegraphy
d. TV
e. None of the above

14. A modulator:

a. Generates the transmitter RF
b. Varies the frequency, amplitude, or phase of a transmitter in accordance with the intelligence.
c. Varies the height of the antenna
d. Filters the pulsating DC
e. None of the above

15. A key-click filter:

a. Helps prevent spurious radiation
b. Softens the key action mechanically
c. Isolates the oscillator from the load
d. Injects the intelligence
e. None of the above

16. A detector is sometimes called:

a. A modulator
b. A demodulator
c. A harmonic
d. A plainclothesman
e. None of the above

17. The symbol for a triode is:

a.

b.

c.

d.

e.

18. The active elements of a triode tube are:

a. Cathode and anode
b. Cathode, heater and plate
c. Cathode, base and collector
d. Cathode, control grid and plate
e. None of the above

19. 1000 kHz =

a. 100 Hz
b. 1 MHz
c. 10,000 Hz
d. 0.1 MHz
e. None of the above

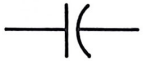
20. The symbol for a semiconductor diode is:

a.

b.

c.

d.

e. 

21. To reduce shock hazard, one should:

a. Keep body from open electronic equipment which is turned on.
b. Be sure equipment is grounded
c. Be sure equipment has good design
d. Be sure antenna wires are kept away from power lines
e. All of the above

22. A milliampere is:

a. one tenth of an ampere
b. one hundreth of an ampere
c. one thousandth of an ampere
d. one millionth of an ampere
e. one thousand amperes

23. A K ohm is a resistance of:

a. one tenth of an ohm
b. one thousand ohms
c. one millionth of an ohm
d. one million ohms
e. None of the above

24. The "Q" signal QRM? means:

a. What is the name of your station?
b. Are you being interfered with?
c. Are you troubled by static?
d. Shall I send more slowly?
e. Shall I stop sending?

25. The abbreviation GMT means:

a. General Motors Transmitter
b. Gigantic Mamouth Transmitter
c. Greenwich Mean Time
d. Government Manual for Transmitters
e. None of the above

26. The maximum allowable modulation % =

a. 50%
b. 100%
c. 150%
d. 200%
e. None of the above

27. A Novice Class license is valid for:

a. 1 year
b. 2 years
c. 3 years
d. 4 years
e. 5 years

28. Which of the frequency bands listed below is **incorrect** for Novices?

a. 3700-3750 kHz.
b. 7.1-7.15 MHz.
c. 7100-7200 kHz.
d. 21.1-21.2 MHz.
e. 28.1-28.2 MHz.

29. The maximum input power to a Novice operated amateur station should be:

a. 50 watts
b. 75 watts
c. 100 watts
d. 125 watts
e. None of the above

30. The maximum financial penalty for violation of the rules and regulations of the FCC is:

a. $250 a day for each day of violation
b. $500 a day for each day of violation
c. $1000 a day
d. $10,000 total
e. None of the above

31. An amateur radio operator should identify his station call at least:

a. Once each 5 minutes of operation
b. Once a day
c. Once each 10 minutes of operation
d. Ten times an hour
e. None of the above

SAMPLE NOVICE TEST (Cont.)

32. One-way communications from an amateur station are allowed:

    a. Never
    b. Anytime
    c. Only for emergency
    d. Only for code practice
    e. None of the above

33. The frequency of a Novice transmitter may be controlled:

    a. By crystal only
    b. By VFO only
    c. By either crystal or VFO
    d. By the National Bureau of Standards
    e. None of the above

34. A novice station may be operated by:

    a. Only Novices
    b. Any U.S. Licensed amateur
    c. Any foreign licensed amateur
    d. Relatives of the Novice only
    e. None of the above

35. When checked against NBS broadcast station(s), the following may be used to measure your transmitted signal frequency:

    a. wave-meter
    b. frequency meter
    c. receiver
    d. All of the above
    e. None of the above

INFORMATION

Hope you made out well on the 'Sample Novice Test'. It is very similar to the one you will take for the FCC to get your license. If you did well on our sample test, then chances are you won't have trouble with the FCC test.

The procedure for applying for a Novice Class license and for obtaining the necessary test is as follows:

1. Obtain a copy of Form No. 610 from the nearest District FCC office. (See the list of district offices & addresses shown in columns 2 and 3)

2. Find a volunteer examiner who meets the following requirements:
   a. Is holder of an unexpired FCC amateur license of General, Advanced, or Extra Class level,

   b. or, Is holder of an unexpired FCC commercial RADIO-**TELEGRAPH**, license,
   c. or, Is currently the operator of a manually-operated radiotelegraph station in the service of the United States.

When your volunteer gets the necessary papers, he will administer the Code tests first . . . which will consist of five minutes of text at 5 words (25 characters) per minute. One minute of copying without error is required to pass . . . and, likewise, one flawless minute of sending is required at 5 WPM to pass.

After passing the code test, the examiner will give you the written test.

Within ten days after passing the code tests, the applicant must send the Form No. 610 and a check or money order for the $9.00 fee to the FCC Licensing Unit . . . Gettysburg, Pa. 17325. Be sure the examiner completes the proper certification on the reverse side of Form No. 610 before mailing it in.

Good luck!

FCC DISTRICT OFFICES

Dist. No. 1
1600 Customhouse
India & State Streets
Boston, Mass. 02109

Dist. No. 2
748 Federal Bldg.
641 Washington St.
New York, N.Y. 10014

Dist No. 3
1005 Customhouse
Second & Chestnut Sts.
Philadelphia, Pa. 19106

Dist. No. 4
819 Geo. M. Fallon Fed. Bldg.
31 Hopkins Plaza
Baltimore, Md. 21201

Dist No. 5
Military Circle
870 Military Highway
Norfolk, Va. 23502

Dist. No. 6
1602 Gas Light Tower
235 Peachtree St., N.E.
Atlanta, Ga. 30303

Dist. No. 7
51 S.W. First Ave.
Miami, Fla. 33130

Dist. No. 8
600 South St.
New Orleans, La. 70130

Dist. No. 9
5636 Federal Bldg.
515 Rusk Ave.
Houston, Tex. 77002

Dist. No. 10
Rm. 13E7; Fed. Bldg.
1100 Commerce St.
Dallas, Tex. 75202

Dist. No. 11
Rm. 1754
312 N. Spring St.
Los Angeles, Calif. 90012

Dist. No. 12
323 A Customhouse
555 Battery St.
San Francisco, Calif. 94111

Dist. No. 13
314 Multnomah Bldg.
319 S.W. Pine St.
Portland, Ore. 97204

Dist. No. 14
8012 Federal Office Bldg.
900 1st Ave.
Seattle, Wash. 98104

Dist. No. 15
504 New Customhouse
19th St. btwn Calif. & Stout
Denver, Colo. 80202

Dist. No. 16
691 New Federal Bldg.
4th and Robert Sts.
St. Paul, Minn. 55101

Dist. No. 17
1703 Federal Bldg.
601 E. 12th St.
Kansas, City, Mo. 64106

Dist. No. 18
1872 U. S. Courthouse
219 S. Dearborn
Chicago, Ill. 60604

Dist. No. 19
1054 New Federal Bldg.
Washington Blvd. & Lafayette St.
Detroit, Mich. 48226

Dist. No. 20
905 Fed. Bldg.
111 W. Huron St.
Buffalo, N.Y. 14202

Dist. No. 21
502 Federal Bldg.
P.O. Box 1021
Honolulu, Hawaii 96808

Dist. No. 22
P.O. Box 2987
322 U.S.P.O. & Courthouse
San Juan, P.R. 00903

Dist. No. 23
Room G-63
U.S.P.O.
4th & G Streets
P.O. Box 644
Anchorage, Alaska 99501

Dist. No. 24
Room 216
1919 M Street N.W.
Washington, D.C. 20554

NOW YOU'VE GOT IT . . . WHAT NEXT?

When that welcome piece of paper comes in the mail with your very own call letters . . . here's a few suggestions.

NUMBER ONE . . . Get on the air!

This will really be your best vehicle for working toward higher licenses. USE IT . . . NOW YOU HAVE IT!

You will find as all others have found before you . . . that first contact is SCARY, EXCITING, EXHILARATING, AND FANTABULOUS "all rolled into one event".

How do you go about getting on the air? May we suggest that you pick up a copy of the ARRL booklet entitled, "Operating an Amateur Radio Station", and a second ARRL booklet entitled, "How to Become a Radio Amateur". There is much in these that won't be pertinent to the beginner . . . but you can read the appropriate parts that will help you, as required.

Something that will be very helpful is to have an experienced Amateur friend work with you to get the transmitter, receiver, antenna and operating position organized and correctly connected. Before operating ANY electronic equipment, it is wise to CAREFULLY READ the equipment manual pertinent to that gear. Especially read, and follow any instructions regarding operation of the equipment.

Once you have acquired the needed equipment, etc. and have your station set up, the best advice we can give you is to use it, and get on the air all you can. You will find that your code speed and your enthusiasm for Amateur Radio will automatically increase if you do this.

There are a number of helpful booklets at your local Radio Shack. Take advantage of these economical aids to advance your knowledge and ability. May we encourage you, as you continue to study for the higher class licenses . . . KEEP PRACTICING YOUR CODE . . . and hopefully, do it "on the air." Listen to the W1AW code practice sessions on your receiver . . . as this is always "good clean code". Its what you need for proper receiving practice.

CONGRATULATIONS ON OBTAINING

YOUR NOVICE LICENSE, AND ON

YOUR DESIRE TO KEEP MOVING

THROUGH THIS BOOK TOWARD

ACHIEVING THE HIGHER LICENSES!

DON'T LET UP NOW . . .

AS THE OLD SAYING GOES . . .

"STRIKE WHILE THE IRON'S HOT!"

CHAPTER 3
THE TECHNICIAN CLASS LICENSE

Again, congratulations on coming this far! You are now beginning to personally experience some of the excitement of "ham" radio, if you have gotten on the air with your Novice license. The ground work that has been laid by your diligent work in learning code and some basic electronic theory will pay great dividends as you continue to work toward the General Class License. In this chapter, however, we simply wish to give you an overview of the Technician Class license privileges, requirements and the like. May we repeat ourselves once more here and say that even though the Technician Class license does not require any more code proficiency than the Novice class . . . we strongly urge you to "continuously continue" your code practice . . . working toward the General Class 13 WPM requirement. The reason we keep telling you to practice, practice, practice is because in order to learn code it takes practice, practice, practice! Now, let's take a quick look at some of the features of the Technician Class license.

INFORMATION

The basic reason the FCC opened this class of license was to encourage radio amateurs to experiment in the "higher frequency" ranges. Radio amateurs, over the years, have made great contributions to technology by being first to perform meaningful experimentation and operation in much of the radio spectrum.

The requirements for acquiring a Technician License boil down to the following:

1. *Must be a U.S. citizen, or a resident alien who has filed "first papers" for citizenship.*
2. *Pass a sending and receiving code test at 5 words per minute (same as Novice).*
3. *Pass a written test on theory and regulations. This is the same as the General class.*

The Technician tests are generally taken by mail under the direct supervision of a General Class or higher licensee. The reason we used the word "generally", is that there is an exception to this. The exception is—if you go to an FCC office to try for a General Class license and you should fail the 13 WPM test for code, but you get 25 characters in a row (equivalent of copying 5 consecutive words at the 13 WPM rate), you may take the written test and have the code credited toward the Technician Class license. If you pass the written theory test, and have met the above 25 character requirement, you will be issued a Technician Class license. This successful passing of the written test **at the FCC office** *can be credited toward your General license, so that to get the General, all that's left for you to do is to pass the 13 WPM code tests at the FCC office. (Sending and receiving).*

REFERENCE & DATA

Code Reminder . . . Hope you have a receiver now and are getting daily "on the air code practice". Keep up the good work. Stop by your local Radio Shack store to select a receiver, antenna and other helpful accessories.

WHAT PRIVILEGES DO YOU HAVE?

For easy reference we are going to list the frequencies and types of transmission you can use as a Technician in chart form in column 2, as we did for the Novice chapter.

That sure looks like a lot to remember . . . but it's not too bad if you remember the following general facts:

Above 145 MHz, all the bands allow A0 thru A5 and F0 thru F5. Above 2300 MHz, all the bands also allow P (pulse) with one exception . . . which is the 10000 to 10500 MHz band.

Even with that crutch, I'll bet you're still wondering what all those letters and numbers mean in the "types of emission" column. Let's put that information in column 2 for you now.

As a "Technician" you may operate any amateur radio station licensed by the FCC so long as you operate it in accordance with the frequency and operating limitations stipulated for Technician Class operation.

The Novice Class power limitation does not apply to a Technician Class Ham—so you've got up to 1000 watts to use at these frequencies.

Another interesting feature of the Technician Class license is that it is needed by many "hobbyists" who operate "radio-controlled" models (airplanes, boats, cars, etc.)

The Technician Class license is valid for five years and is renewable, using normal renewal forms, etc., from the FCC. Be aware that there are stipulations at renewal that you must have operated an amateur radio station for a minimum total of either 2 hours operating time during the last three months, or 5 hours operating time during the last 12 months of the license term.

ACTIVITIES

Technician Class amateur activities are multifaceted and include such things as: "ragchewing" (talking with other hams on the air); experimental work at the high frequencies; Radio-controlled models; Radio "net" schedules (where a group of amateurs "check-in" to an organized "network" of hams who meet on-the-air at specific times and frequencies for the purposes of passing "traffic" [messages], etc.); Emergency communications networks; etc.

As you can see, the scope of activities open to you as a "Technician" has broadened considerably with new frequencies, and various emission "modes" available to you.

May we encourage you to continue now and work on the theory in the next chapter (General Class License) so that you may get your Technician class license at the earliest possible date. And, of course, keep working on that code so you will achieve that General Class License you have been working so diligently for.

In other words . . . KEEP UP THE GOOD WORK! Each "notch" you move up will encourage you to reach for the next one . . . and remember, our goal in this book is to help you get from 5 watts to 1000 watts through obtaining an FCC license that gives you this privilege.

Good luck as you now begin to study the challenging and interesting electronics theory and for the General Class license.

MHz	Types of Emission
50.1 - 54.0	A1, A2, A3, A4, A5, F1, F2, F3, F5
51.0 -54.0	AØ
145 - 148	AØ thru A5 FØ, F1, F2, F3, F5
220 - 225	AØ thru A5 FØ thru F5
420 - 450*	AØ thru A5 FØ thru F5
1215 - 1300	AØ thru A5, FØ thru F5
2300 - 2450	AØ thru A5, FØ thru F5, and P
3300 - 3500 & 5650 - 5925	AØ thru A5, FØ thru F5, and P
10000 - 10500	AØ thru A5, FØ thru F5
21000 - 22000 & above 40000	AØ thru A5, FØ thru F5, and P

*In certain areas of the country, plate input power must not exceed 50 watts. Refer to FCC rules Section 97.61(b) (9) at the back of the "ARRL License Manual" for details.

TYPES OF EMISSION DEFINED

- AØ = Steady, unmodulated pure carrier.
- A1 = Telegraphy on pure "continuous" waves. (In effect, keyed RF carrier)
- A2 = Amplitude tone-modulated telegraphy.
- A3 = AM Telephony including single-side-band and double-sideband with full, reduced, or suppressed carrier.
- A4 = Facsimile.
- A5 = Television.
- FØ = Steady, unmodulated pure carrier.
- F1 = Carrier-shift telegraphy.
- F2 = Audio frequency-shift telegraphy.
- F3 = Frequency, or phase-modulated telephony.
- F4 = FM facsimile.
- F5 = FM television.
- P = Pulse emissions.

CHAPTER 4
THE GENERAL CLASS LICENSE

Well, this is it! This is the chapter you've been working toward. When you have mastered the information in this chapter, you should be well prepared for the Technician and General Class written examination. In order to get that coveted General Class license, it will require continued diligence, on your own, to reach that 13 WPM code proficiency . . . but, we have confidence in you . . . you can do it!

In early pages of this book, we tried to "spoon feed" you. Now that you have some background, we will begin to treat you like an electronic technician in this chapter. By this, we simply mean that there will be less "spoon feeding". We will expect you to "recycle" yourself when required, without having to be told. We will want you to carefully study any figures, charts or drawings associated with the text in order to get the full significance—and we won't spell out every single detail in words. In other words . . . we're going to force you to do some reasoning on your own . . . just like you will have to do on the General test.

Also, in this chapter, there will be a number of "schematic" diagrams given in which you can either use a "pencil and paper" method of analyzing the parameters, and/or, you can connect the circuits, if you have the parts, and make actual measurements to verify your "theory" calculations. Virtually all the parts and supplies can be purchased at your Radio Shack Store.

Generally, we will try to give the theory in this chapter by topic, so if you need more study in a particular area of theory you can easily find the segment of the chapter devoted to that area for restudy (since information on a particular topic, for the most part, will not be scattered throughout the chapter.) Of course, there will be some cases of "overlapping" information.

Some of the basic topics include: Privileges and requirements of General Class; DC and AC circuit theory; Active and passive electronic components; Various electronic systems; Applications of various electronics components and circuits; Significant electronic terms definitions; Antennas and feedlines; Rules and regulations; and various operating procedures.

Bon voyage through this interesting and challenging chapter!

REQUIREMENTS

To obtain a General Class license you must pass a receiving and sending code test at 13 words per minute at an FCC office. Also, you must pass a written examination covering general amateur practice and regulations (approximately 1/3rd the test); and basic radio theory (2/3rds the test). The code test lasts for five minutes . . . of which you must copy a minimum of one minute without error. The text is plain language and will include some numbers and punctuation, and several comon procedural signals, such as: AR, SK, BT, and AS.

The written test consists of 50 questions of the multiple-choice type. To pass you must get a grade of 74% or better.

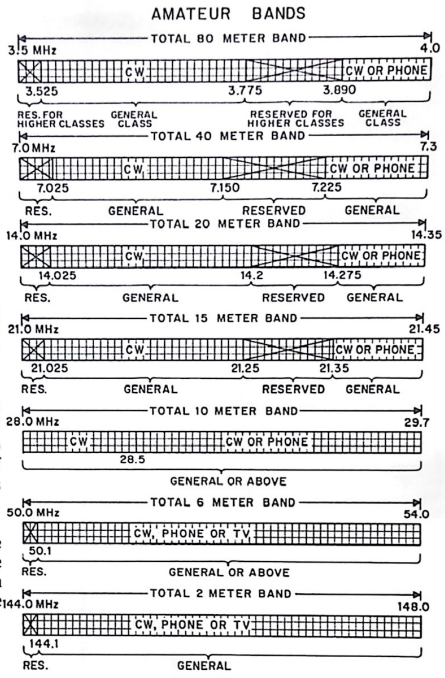
PRIVILEGES

Lots of Hams automatically think in terms of more power when they get to the General Class. Now they can go all the way up to 1000 watts. This is true, but we'd like to remind you that power alone does not insure good DX or solid local "copy. Lots of Hams find it particularly challenging to deliberately limit themselves to low power. Hams in many countries are limited to 200 or even 75 or 50 watts.

The General Class licensee can operate in any of the bands open to amateur radio operators with the exception of certain segments of certain bands which are reserved for "Advanced Class" and "Amateur Extra Class" licensees.

Study the chart/s shown in column 2 and learn particularly the frequencies in each band for CW (&RTTY), and **VOICE**. Notice that CW (A-1) is allowed throughout each band, but, voice is limited to certain sections of each band. BE SURE to study which segments of each band are NOT OPEN to General Class . . . that is, the part/s of each band reserved for Advanced or Extra Class licensees.

For example: in the 80 meter band the General cannot use the "bottom" 25 kHz of the CW band, or the "bottom" 115 kHz of the "Phone" (Voice) segment of the band. Study the charts and learn the frequencies for General Class for each of the bands, then try the checkpoint.



CHECKPOINT:

Answer the following questions in regard to GENERAL CLASS license privileges only!

1. For CW operation on the 80 meter band, the frequency segments that may be used are from _____ MHz to _____ MHz, and from _____ MHz to _____ MHz.

2. Phone (voice) operation on the 80 meter band is from _____ MHz to _____ MHz.

3. For the 40 meter band; CW operation is from _____ MHz to MHz and from _____ MHz to MHz.

4. For the 40 meter band; phone operation is from _____ MHz to _____ MHz.

5. For 20 meters:
   a. CW operation is from _____ MHz to _____ MHz, and from _____ MHz to _____ MHz.
   b. Phone is from _____ to _____ MHz.

6. For 15 meters:
   a. CW operations is from _____ to _____ MHz and from _____ to _____ MHz.
   b. Phone is from _____ to _____ MHz.

CHECKPOINTS

7. For 10 meters:
   a. CW is from _____ to _____ MHz.
   b. Phone is from _____ to _____ MHz.
8. For 6 meters:
   a. CW is from _____ to _____ MHz.
   b. Phone is from _____ to _____ MHz.
9. For 2 meters:
   a. CW is from _____ to _____ MHz.
   b. Phone is from _____ to _____ MHz.

ANSWERS:

1. **3.525** to **3.775** MHz and **3.890** to **4.0** MHz.
2. **3.89** to **4.0** MHz.
3. **7.025** to **7.150** MHz and **7.225** to **7.3** MHz.
4. **7.225** to **7.3** MHz.
5. **14.025** to **14.2** MHz, and **14.275** to **14.350** MHz.
6. **21.025** to **21.250** MHz and **21.350** to **21.450** MHz.
7. **28.0** to **29.7** MHz. **28.5** to **29.7** MHz.
8. a. **50.1** to **54** MHz.
   b. **50.1** to **54** MHz.
9. a. **144** to **148** MHz
   b. **144.1** to **148** MHz.

Hope you did all right on that checkpoint! Knowing these frequency limits is not only important for the test, but later for operating on the air. Knowing these limits and abiding by them will help prevent you from getting any "pink tickets" (notices of violation) from the FCC. Study them until you know them!

As a holder of a General Class license, you will also have the privilege or right to conduct and or supervise code tests and written examinations (if you are over 21 years old) for Novice, Technician and Conditional class licenses which are available via the "mail method".

As you can see, when you get your General Class license, you have truly gone from "5 watts to 1000 watts" as far as privileges are concerned . . . and in additon, have available for your use a myriad of frequencies.

You'll be thankful for the rest of your life that you put forth the effort and study neccessary to reach the goal of getting that "General".

Now that you have the "general" idea regarding the requirements and privileges of a "General", we'll move on and begin the "brasstacks" learning you need to acquire that license.

DC & AC FUNDAMENTALS

Let's begin by giving you some review practice on Ohm's Law . . . but before we do that, we'd better teach you the color code for resistors so you can actually connect the circuits we'll be giving you for practice from here on. Also, you WILL need to know the color code when you take the FCC test . . . so let's interject that bit of learning right here, as you begin studying DC and AC circuits (which obviously use resistors).

THE RESISTOR COLOR CODE

Because many resistors are physically small in size, it would be impossible to write their "ohmic" value in printed letters on the side or end. For this, and other reasons, a method has been devised which makes it possible for technicians to tell at a glance the value of a resistor. This method is called "color coding". As the name suggests . . . different colors represent different numbers, and the way the colors are put on the resistor reveal its value in ohms.

The system we want you to learn is called the "Band" system. The color coding appears on the resistor as bands or stripes of color.

The initial step in learning the color code is to learn the numerical significance of each color used. Note the chart in column 2. There have been numerous "crutches" used to enable easy learning of the sequence of colors used in "color-coding", however, the one we shall use is:
"**B**ig **B**oys **R**ace **O**ur **Y**oung **G**irls, **B**ut **V**iolet **G**enerally **W**ins!" Notice that the sequence of first letters in each word in the sentence is the same as the sequence of colors representing the numbers 0-9, in that order.

In addition to those colors shown in the chart . . . there are two other "special" colors used in color coding resistors. These colors are Gold and Silver. Before we learn the significance of these two colors, we want you to memorize the color significance chart. After you have mastered "what color represents what number" . . . try the quick checkpoint!

COLOR SIGNIFICANCE CHART

COLOR	VALUE
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

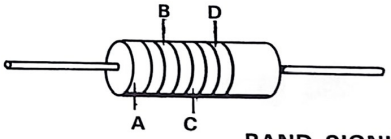
CHECKPOINT:

WITHOUT LOOKING BACK AT THE COLOR SIGNIFICANCE CHART . . . fill in the blanks below with either the appropriate number, or color as required.

1. Green = _____
2. The number 2 is represented by the color _____
3. Brown = _____
4. 3 = what color? _____
5. Black = _____
6. 9 = what color? _____
7. Blue = _____
8. Gray = _____
9. 4 = what color? _____
10. 7 = what color? _____

ANSWERS:

1. 5
2. Red
3. 1
4. Orange
5. 0
6. White
7. 6
8. 8
9. Yellow
10. Violet



Now that you know the main colors used in color coding . . . you must learn the meaning of the various bands and their placement.

Carefully study the "BAND SIGNIFICANCE CHART" shown in the next column.

Now let's mention the Gold and Silver colors again. You will only find them used as either the third band (decimal multiplier band), or in the fourth band (tolerance band). Look at the description for these colors in the next column.

BAND SIGNIFICANCE

Band A—1st significant figure of resistance value in ohms.
Band B—2nd significant figure of resistance value in ohms.
Band C—Decimal multiplier
Band D—Tolerance in percentage (If no fourth band, tolerance is 20 per cent.

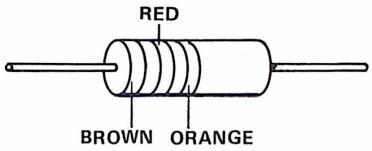
Gold = 5% tolerance, when used as fourth band (band D)
Gold = 0.1 multiplier, when used as third band (band C)

SILVER = 10% tolerance, when used as fourth band (band D)
SILVER = 0.01 multiplier, when used as third band (band C)

Okay! Let's put it all together and let you practice reading the color code. You will find that as you use this information by actual practice, it will only be a short time before you have the color code well in mind. THE KEY HERE IS **USE IT!** The more you practice using it, the quicker it will become "second nature" to you.

Just before we give you some practice problems, let's give you a couple of examples to help you get started.

Example: If we were looking at a resistor whose 1st band was Brown, 2nd band was Red, and third band was Orange . . . here's how you decode it:



The first number in the resistor's value would be "1" . . since Brown represents 1. The second number would be "2", since Red = 2. Since Orange is the third band, or "multiplier" band and orange means 3 . . . then to get the value of the resistor, you would write down 12 . . . followed by three zeros, (since the "multiplier band simply tells you how many zeros to add after the first two significant numbers) . . . The value is 12,000 ohms, or 12K.

Since there was no fourth color band on this resistor, the resistor tolerance is 20%.

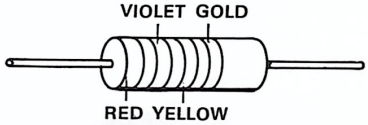
What do we mean by "tolerance"? Simply this. This resistor could be as low in value as 20% below the color-coded 12K and still be "within tolerance" . . . or as high in value as 20% above 12K, and still be in tolerance. In other words, if this resistor were anywhere between 9.6K and 14.4K ohms, "it lived up to its specifications".

Here's one more example:

A resistor is color-coded Red-Violet-Yellow-Gold, in that order. Its value is: 270,000 ohms with 5% tolerance. The first color, red = 2; the second color violet = 7; and the Yellow = 4 . . . and as a multiplier band means 4 zeros after the first two numbers; and the Gold as a 4th band means a 5% tolerance.

Now it's your turn. Fill in the Band System Exercise Chart shown in column 3.

CHECKPOINT:



1st Color	2nd Color	3rd Color	4th Color	Ohms	% Toler.
1. Red	Blue	Yellow	Gold		
2. Brown	Black	Black	Silver		
3. Brown	Black	Red	None		
4. Orange	White	Orange	Gold		
5. Yellow	Violet	Yellow	Silver		

ANSWERS:

1. 260K with 5% tolerance
2. 10 ohms with 10% tolerance
3. 1000 ohms with 20% tolerance
4. 39K with 5% tolerance
5. 470K with 10% tolerance

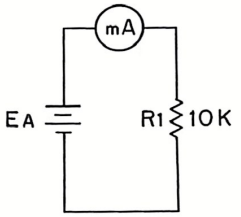
INFORMATION

Did you catch that tricky one with Black as the third band? Whenever black is used as a multiplier (third band), it means to add "zero" zeroes . . . and simply read the first two significant digits . . . in our sample the value is 10 ohms. Remember this one, for it appears quite often in real life. Also, we could have tricked you by putting gold or silver in the third band position. All you have to do is move the decimal in accordance with the color. Example: if the first two numbers were decoded as 15, and the third band was Gold (a 0.1 multiplier) . . . then the resistor would be a 1.5 ohm resistor. If Silver were the 3rd band . . . the value would be 0.15 ohms.

THE ONLY WAY TO LEARN THE COLOR CODE IS TO USE IT! We realize that we don't have room enough in this book to give you all the practice you need . . . so it's up to you! Every time you see a resistor . . . "decode it". It's a lot of fun to see how quickly and accurately you can decode it. You'll be amazed at how quickly those colors will almost look like numbers to you, if you will practice.

Look at the diagram in column 2 and fill in the appropriate blanks in the checkpoint in column 3. HINT: Start by writing the OHM'S LAW formula for voltage . . . then substitute the appropriate values of current and resistance into the formula. Use the blank space on these pages for your calculations, etc.

REFERENCE & DATA



CHECKPOINTS

CHECKPOINT:

If the current meter is reading 2 mA . . . What is the value of the "applied voltage"?

E_A = _____ volts.

ANSWER:

E_A = **20** volts

Here's the procedure:

Ohm's Law formula for voltage is:

$E = I \times R$

Substituting, we get:

$E = 0.002$ A. x 10,000 ohms = **20 volts.**

That wasn't bad was it? Here's another little hint . . . whenever you multiply milli-units times kilo-units . . . the answer is in units. The reason is that a milli-unit is "one-thousandth" of a unit and the kilo-unit is "one thousand" units . . . so when you multiply one-thousandth by one thousand you "end up" with 1.

Let's see if you remember the power formula.
For the same circuit . . .
how much power does R dissipate? Don't forget, in order to prevent simple errors . . .

1. *Write down the appropriate formula, then . . .*
2. *Substitute the appropriate values . . . keeping track of the decimals.*

Work out the answer and fill in the Checkpoint blank.

CHECKPOINT:

The power dissipated by R_1 (P_{R_1}) = _____ mw. (milliwatts)

ANSWER:

40 mw.

Did you use the P = E x 1 formula? Sure! That would have worked . . . so would the I^2 x R formula, and the E^2/R formula, since you had E, I, and R all as "knowns." Try the next checkpoint.

CHECKPOINT

1. If all that is known is current and resistance, which power formula would you use? P =

2. If all that is known is voltage and resistance, which formula would you use? P =

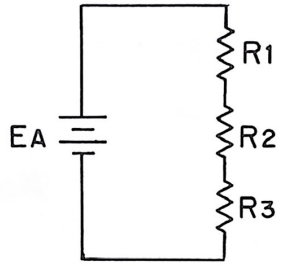
ANSWER

1. $P = I_2R$

2. $P = \frac{E^2}{R}$

THE SERIES CIRCUIT

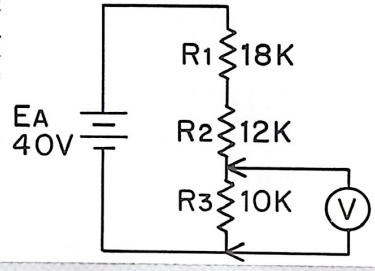
That was a simple 1-resistor circuit. Most circuits you will have to analyze will have more than one component involved . . . so let's move on now and discuss the important characteristics of SERIES CIRCUITS. A series circuit is simply a circuit where two or more elements or electrical components are connected "in tandem"—like links in a chain. See how this is illustrated in the schematic of a three-element series circuit.



Notice how one end of R_1 connects to one end of R_2; the other end of R_2 connects to one end of R_3 . . . and so on. Looking at this diagram of a series circuit . . . how many "PATHS" for electrical current do you see?

If you said one, you were correct. Looking at this circuit we could say that the "electrons" leave the negative side of the battery (bottom of the schematic) . . . pass through R_3, then R_2, then R_1 . . . then back to the positive side of the source (battery). This means that the same current passes through all the resistors. ONE OF THE KEY FACTS TO REMEMBER ABOUT SERIES CIRCUITS IS: **THE CURRENT IS THE SAME THROUGH ALL ELEMENTS IN SERIES!** Remember this fact—it will go a long way in helping you to analyze series circuits.

Let's give you a practical problem that uses this fact. Look at the diagram in column 2 and fill in the blanks in column 3 as appropriate. Use blank space on these pages for your calculations.



Let us suggest that if you have the parts, or want to pick them up at Radio Shack, you can verify these calculations by actually measuring the voltages, etc. While you are at it, you might want to look at the book Radio Shack publishes on the subject of using a VOM.

CHECKPOINT

If the voltmeter reads 10 volts, the current through R_3 must be _____ mA. (Hint: I = E/R)

Since this is a series circuit, the current through R_2 must be _____ mA. The current through R_1 is _____ mA.

Knowing the current through R_2 and R_2's resistance, we can calculate the voltage drop across R_2 as: E_{R_2} = ____ volts. Also, we can calculate the voltage drop across R_1. E_{R_1} = _____ volts.

ANSWERS:

I_{R_3} = 1 mA.
I_{R_2} = 1 mA.
I_{R_1} = 1 mA.
E_{R_2} = 12 volts
E_{R_1} = 18 volts

INFORMATION

Let's take a closer look at our three-element series circuit and "pick-up" some other very important facts regarding series circuits.

Fact: **THE TOTAL RESISTANCE OF A SERIES CIRCUIT IS EQUAL TO THE SUM OF ALL THE INDIVIDUAL RESISTANCES IN SERIES!** For our sample circuit then: RT (total res.) = $R_1 + R_2 + R_3$ Thus: R_T = 18K + 12K + 10K = 40,000 ohms (40K).

Another way we could have solved for R total is by using Ohm's Law as follows:

$R_T = E_T/I_T$ which simply means total resistance = total voltage divided by total current . . . so for our sample circuit:

R_T = 40v/1mA = 40K ohms.

Many, many times in working on electronics calculations you will be using this version of Ohm's Law . . . so here's another quickie hint at no extra charge! Whenever you divide units by milli-units . . . the answer is in K units. Most of the time when you are solving for resistance in electronic circuits you will be working with volts and milliamps . . . so remember this statement . . . **volts divided by milliamps = Kilohms.**

Let's look at our sample circuit again and make another important observation. ***FOR SERIES CIRCUITS: THE APPLIED VOLTAGE (E_A OR E_T) IS EQUAL TO THE SUM OF THE INDIVIDUAL VOLTAGE DROPS!***

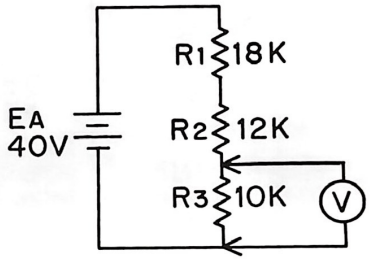
For our sample circuit then, E_A (E applied) must equal $E_{R1} + E_{R2} + E_{R3}$; or in other words: 18v + 12v + 10v . . . hence E applied or E_T = 40 volts.

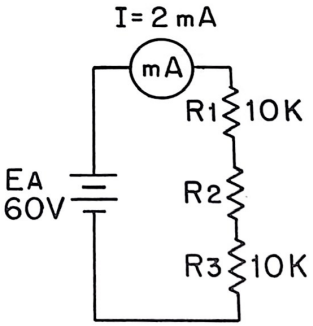
Putting these three important facts together (regarding series circuits) . . . you have tremendous flexibility in solving series circuits. Those 3 key facts again are:

1. ***Current is the same through all parts of a series circuit.***
2. ***Total resistance is equal to the sum of all the resistances.***
3. ***Total voltage is equal to the sum of each of the individual voltage drops.***

O.K. Here's a "brain twister" problem to see if you can begin to apply these facts to a practical problem. Give it your best effort! Try not to look ahead to the answer until you've really given it "a college try".

REFERENCE & DATA





CHECKPOINTS

CHECKPOINT:

For the circuit shown in column 2 find the following:

E_{R1} = _____ volts
E_{R3} = _____ volts
E_{R2} = _____ volts

R_2 = _____ K ohms
I_{R3} = _____ mA.

P_T = _____ mW.

All right! Now that you've given it the "college try", look at the explanation and answers in the "Answers" section.

ANSWERS:

Here is the typical approach to solving this circuit and getting the answers called for:

First . . . recall that the current through all parts of a series circuit is the same . . . therefore, there is 2 mA. of current flowing through R_1 and through R_2 and also through R_3.

Second . . . to find E_{R_1} you simply use Ohm's Law and substitute the appropriate numbers . . . in this case:
E_{R_1} = I (through R_1) x R_1
E_{R_1} = 2 mA. x 10K = **20 volts**

Third . . . to find E_{R_3} simply multiply the current through R_3 (2 mA.) times R_3 (10K) and you get **20 volts.**

Fourth . . . in order to find E_{R_2}, there are two "nifty" approaches you might use:
One way is using the fact that the Total or Applied voltage for a series circuit is equal to the sum of all the individual voltage drops. Using this fact and knowing that there is 60 volts applied to this series circuit . . . and that R_1 and R_3 are each dropping 20 volts . . . then logic says the remaining 20 volts must be dropped by R_2 . . . AND IT IS! A second way is through "another back door" approach, namely: Find R TOTAL by using the formula:
R_T = E_A/I_T (E applied divided by I total), yielding 60v/2mA. = 30K. Since R_T in a series circuit equals the sum of the individual resistances, then, by logic, R_2 must equal 10K.

Knowing that R_2 = 10K . . . then you can say E_{R_2} = 2 mA. x 10K = **20 volts.**

Another way to find R_2's value is to understand that E_{R_2} has to be 20 volts, since E_{R_1} + E_{R_3} = 40 volts, and there is 60 volts applied to the circuit. Using the fact that E_{R_2} is 20 volts, and knowing that the current through R_2 must be 2 mA. since this is a series circuit, you can then use the formula:
R_2 = E_{R_2}/I_{R_2} or 20v/2mA. = **10K.**

The current through R_3 (I_{R_3}) is obviously **2 mA.**, since the current is the same throughout any series circuit.

To solve for the circuit's P_T (total power dissipation), we can either solve each individual resistor's power dissipation . . . then add them up to get total power . . . or, in this case, since we know E total and I total, simply use the formula:
P_T = E_T x I_T
P_T = 60 v x 2 mA.
P_T = **120 mW.** (milliwatts)

See how one fact hinges on another. A general rule for solving electronic problems is to "COLLECT ALL YOUR KNOWNS AND GIVENS". When possible, make a diagram if one is not given . . . then label the diagram appropriately with the known facts . . . this will usually help you organize your thinking, and visualize the approach to use.

INFORMATION

O.K. Let's make mention of a couple more facts that are very practical . . . even though you may not be called upon to analyze a circuit with these conditions on an FCC exam.

Fact number one relates to the effect of an "OPEN" in a series circuit. By an "open" we mean that for some reason or another, the current path is broken through a given part of the circuit. For example . . . if a resistor were to physically break in half, it would create an open. If ANY PART OF A SERIES CIRCUIT IS OPEN . . . THE ONLY CURRENT PATH THROUGH THE CIRCUIT IS BROKEN . . . HENCE CURRENT WILL DECREASE TO ZERO THROUGHOUT THE SERIES PATH. Of course, an open can be caused by a wire becoming disconnected from a terminal or component, etc. When current is zero, then the IxR drop across all other components, except the open one, is zero. Across the open portion of the circuit, one would measure E applied, since there are no "IxR" drops to subtract from E_A . . . THE POTENTIAL DIFFERENCE ACROSS THE OPEN WILL BE E_A.

Fact number two relates to the effect of a "SHORT" in a series circuit. If any resistance is shorted out (becomes close to zero ohms), then R total will decrease . . . causing I total to increase. If the current through the circuit increases . . . then the IxR (voltage) drops across the "unshorted" components will increase proportionately . . . and the voltage drop across the shorted part of the circuit will decrease to zero . . . since E = IxR, and R (for the shorted portion) has become virtually zero . . . anything times zero is still zero, hence E = zero.

Of course there are many adverse effects from a "shorted" part, or all, of a circuit. Everything from blown fuses to destroyed circuit elements can (and often do) happen when shorts occur. How much damage is done usually depends on how much "unshorted" resistance is left in the circuit to limit current.

Here's a summary of key facts regarding series circuits . . . remember these and understand them, and you will be able to "think your way" through almost any problem involving series circuits.

Facts: (for series circuits)

1. Total resistance (R_T) equals the sum of the individual resistances . . . or:
   $R_T = R_1 + R_2 + \ldots$ and so on.

2. Total voltage equals the sum of the individual voltage drops . . . or:
   $E_T = E_{R_1} + E_{R_2} + \ldots$ and so on.

3. Total power equals the sum of the individual power dissipations, or:
   $P_T = P_{R_1} + P_{R_2} + \ldots$ and so on.

REFERENCE & DATA

CHECKPOINTS

4. The Ohm's Law formulas and the Power formulas can be used to solve values for any part of a series circuit . . . or the whole circuit . . . simply by using the appropriate values for the portion of the circuit being analyzed.

5. If an open occurs in a series circuit, the total current will decrease to zero and the total resistance of the circuit becomes infinitely high.

6. If a "short" occurs in a series circuit, total resistance of the circuit will decrease and total current will increase. If the WHOLE CIRCUIT were shorted, the total resistance would become zero ohms and the total current would go as high as the source of voltage and current would allow.

7. THE KEY FACT TO REMEMBER IS THE CURRENT IS THE SAME THROUGHOUT A SERIES CIRCUIT. Many other facts hinge on this one.

Some final observations we would like to point out in concluding our little discussion on series circuits:

Since each voltage drop is equal to I x R . . . and the I is the same through all components in series . . . then, it becomes obvious that the voltage drop across any given component is related to its R compared to the other R's in the circuit. In other words . . . If R_1 is 20K and R_1 is 10K . . . then R_2's voltage drop would be double that of R_1. This brings about a very interesting point . . . "THE PERCENTAGE OF E APPLIED DROPPED BY ANY GIVEN COMPONENT IS THE SAME AS THIS COMPONENT'S RESISTANCE VALUE IS OF TOTAL RESISTANCE!"

This means if R_3 is equal to 1/10th of the circuit total resistance . . . then, 1/10th of E applied will be dropped by R_3.

This fact also points out that in a series circuit . . . resistors of equal value will drop the same voltage!

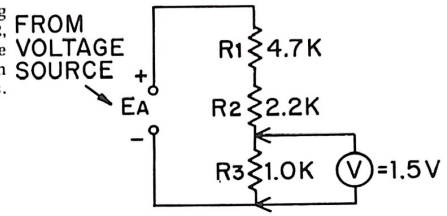
For a series circuit, the largest value resistor will dissipate the most power. (SAME IDEA AS THE VOLTAGE DISTRIBUTION). As you can see, since P = E x I, and I is the same through all components . . . then the component with the highest voltage drop will dissipate the most power. And, for reasons earlier, the E (I x R drop) will be highest across the resistor of the highest resistance value.

I hope we haven't discouraged you by giving you so many facts "in one lump". **What you have just covered is really foundational to all circuit analysis** . . . and will serve you well the rest of your life. Try not to memorize these facts . . . but to UNDERSTAND THE CONCEPTS.

INFORMATION

Let's see if you can "put it all together" and solve an interesting series-circuit problem. Get the "info" from the circuit in column 2, and determine the answers asked for in the checkpoint. Calculate as required in the blank portions of these pages . . . if possible when through . . . verify by actual circuit hookup and measurements. Good luck!

REFERENCE & DATA



CHECKPOINTS

CHECKPOINT:

Find the Following:

R_T = _____
I_T = _____
E_T =
P_T = _____
E_{R_1} = _____
P_{R_2} = _____

What fractional part of E_A is E_{R_3}? _____

ANSWERS:

As a form of review . . . let's "logic" you through this problem step-by-step.

R_T, or total resistance, was the first electrical parameter asked for. By remembering that in a series circuit the total resistance simply equals the sum of the individual resistances . . . you should have simply added 4.7K + 2.2K + 1.0K and arrived at **7.9K** as your answer.

Next parameter asked for was total current. Here's a key step in solving a series circuit. Once you know the current through any part of a series circuit . . . you automatically know the current through all the components in series, since the current is the same through all parts of a series circuit. Just about everytime you have a circuit problem . . . the first thing to look for is any part of that circuit . . . or any component about which you know . . . or are given TWO KNOWNS (or parameters). In this case we have such a condition for R_3. We know its resistance value, AND we know the voltage dropped across it . . . so we can easily solve for the current through it by: $I_{R_3} = E_{R_3}/R_3$. From this we get: I_{R_3} = 1.5v divided by 1.0K . . . and thus I_{R_3} = **1.5 mA.** Since the current is the same through all parts of a series circuit . . . this is also the value for I total . . . therefore, **I_T = 1.5 mA.**

Now that we know the current through all the components, and we were given each component's resistance value . . . we have TWO KNOWNS about each component and the rest is easy.

To solve for **total voltage** (E_T) we simply use "good ole Ohm's Law" again: $E_T = I_T \times R_T$, OR, E_T = 1.5 mA. x 7.9K = **11.85 volts.**

Next on the agenda was total power calculation. You should have written down the formula: $P_T = E_T \times I_T$ and substituted: P_T = 11.85v x 1.5 mA to get the answer: **17.77 mW.** (milliwatts). Incidentally, you could have used: $I_T^2 \times R_T$, OR E_T^2/R_T and gotten the same results. Usually it's easier though . . . if you know both E and I, to use the version of the power formula that doesn't require any "squaring" . . . because then you have to perform two mathematical functions . . . "squaring" and then either multiplication or division (depending on which formula you used).

O.K. To solve for E_{R_1}, just multiply the current through it by its resistance value to get its **"IR"** drop. Answer is: **7.05 volts.**

To get P_{R_2} requires two operations no matter what approach you use . . . so let's use $I_{R_2}^2 \times R_2$ here, and get: P_{R_2} = 1.5 mA^2. x 2.2K = **4.95 mW.** (Watch out for those decimals whenever you square with them.)

ANSWERS (Cont)

Last but not least . . . we asked for what fractional part of the applied voltage was dropped across R_3. Remember our statement that the part of E_A dropped across any component is the same as that component's fractional part of R_T (for series circuits). O.K. R_3's resistance is 1.0/7.9th of the total resistance . . . so it will drop 1/7.9th of E_A . . . OR **11.85v/7.9 = 1.5v.**

You already knew that E_{R_3} was 1.5 volts, because we gave you that. Also, you knew that E_A was 11.85 volts because you calculated that . . . so you may have simply said that E_{R_3} was equal to 1.5/11.85ths of E_A . . . and still be perfectly correct. The key point we want to bring out here though is the fact that the "distribution" of voltage around a series circuit is the same as the "distribution" of resistance. You'll use that fact many times as a Radio Amateur and/or an electronic technician.

Trust that that little problem and step-by-step discussion of the answers was of some help to you. Repeating, the key things to remember about the series circuit are:

1. **Only one path for current.**
2. **Current is the same throughout.**
3. **Total R = sum of all R's.**
4. **Total E = sum of all E's.**
5. **Total P = sum of all P's.**
6. **Voltage distribution around circuit is same as resistance distribution. (Therefore, largest R drops most voltage, smallest R the least, etc.)**
7. **Power dissipation is greatest on largest R, etc. (Same principle as the E distribution . . . since I is same through all . . . then ExI will be largest where R is largest, etc.)**
8. **Ohm's Law and Power Formulas are used to solve unknowns.**

O.K. It's time to move on to "Parallel Circuits".

INFORMATION

THE PARALLEL CIRCUIT

The reason we took so much time looking at principles and concepts in **series circuits** was because you will be using the same general approach in solving all types of circuit problems, and we wanted to give you a good foundation to work from.

Remember that a series circuit could be defined as a circuit where all the components were connected "in tandem", and there was only one path for current flow . . . well, a parallel circuit differs in these two basic points. **First**, a parallel circuit is one in which there are TWO OR MORE CURRENT PATHS. **Second**, the components ARE NOT connected "in tandem". Study the pictorial and schematic diagrams in column 2 illustrating these facts.

Notice that when total current leaves the negative side of the source, there is one path . . . but soon it arrives at a "junction" where R_1 and R_2 join . . . and the current **divides** into TWO paths (I_1 and I_2). *I_1 passes through R_1 . . . I_2 passes through R_2 . . . then the two currents JOIN again at the top of R_1 and R_2 at the junction of those two resistors, and we now have total current ($I_1 + I_2$) traveling from the junction back to the source through the single-wire path. As you see . . . the parallel circuit offers more than one current path. Also, the components are not connected "in tandem", but rather "in a parallel configuration" with "ends common."*

Since their ends are connected together, another valuable fact to remember about components "in parallel" is that the VOLTAGE ACROSS ALL PARALLEL COMPONENTS IS THE SAME! In the case of a "simple" parallel circuit, the voltage across all "branches" is equal to E applied . . . since they are each in parallel with the source as well as being in parallel with each other.

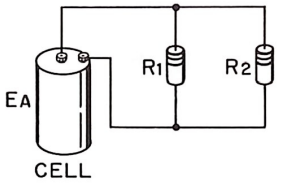
Notice, we used the term "branch" to indicate one path.

In our earlier illustration then, I_1 represents the "branch current" through R_1 and I_2 is the symbol we used to indicate the "branch current" through R_2.

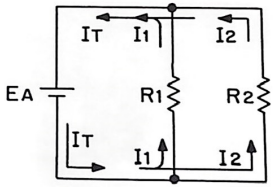
This brings us to a third important fact to remember about parallel circuits. Each branch current is INVERSE to its branch resistance. This simply means that the higher the branch resistance . . . the lower the branch current. Makes sense doesn't it!

Ohm's Law told us that current is inverse to resistance when it says that I = E/R. This means that if branch No. 1 has twice the resistance of branch No. 2 . . . then the current through branch No. 1 will be half that of branch No. 2's current . . . since both R's have the same voltage across them.

REFERENCE & DATA



Pictorial of a Parallel Circuit



Schematic of same Parallel Circuit

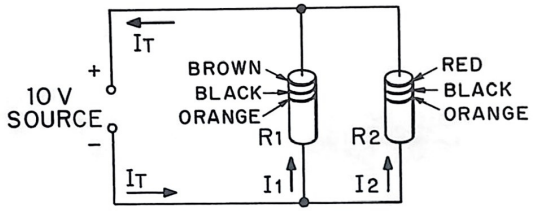
CHECKPOINTS

O.K., here's the three important facts we've mentioned so far in regard to parallel circuits:

1. **More than one path for current flow.**
2. **Voltage across parallel components is the same.**
3. **Current through any given branch is inverse to its resistance value.**

All right! Let's have you put these three facts . . . plus all you've learned previously about color code, Ohm's Law, etc., together to solve a problem involving a parallel circuit. Good Luck!

Look at the "pictorial" diagram in column 2 . . . then use this information to perform calculations as required in the "Checkpoint." Use the blank spaces on these pages for your calculations.



CHECKPOINT:

1. What is the value of R_1?
   R_1 = _____ K ohms.
2. What is the value of R_2?
   R_2 = _____ K ohms.
3. What is the value of branch current I_1?
   I_1 = _____ mA.
4. What is the value of branch current I_2?
   I_2 = _____ mA.
5. What is the value of E_{R_1}? _____ v.;
   E_{R_2}? _____ v.; E_A? _____ v.
6. What is the value of
   P_{R_1}? _____ mW.
7. What is the value of
   P_{R_2}? _____ mW.
8. What is the value of
   I_T? _____
9. What is the value of
   P_T? _____ mW.

ANSWERS:

1. **10K**
2. **20K**
3. **1 mA.**
4. **0.5 mA.**
5. **10v; 10v; 10v.**
6. **10 mW.**
7. **5 mW.**
8. **1.5 mA.**
9. **15 mW.**

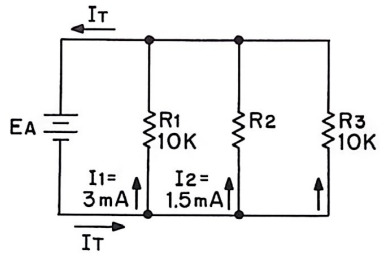
O.K. Observation time! We should be able to arrive at some meaningful conclusions so let's do!

Did you notice that branch No. 2 had twice the resistance of branch No. 1 . . . and half the current? Just like old George Simon Ohm told us . . . right? Did you also notice that since the E was the same across both branches . . . the power dissipated by branch No. 2 was only half that dissipated by branch No. 1? Here's an interesting conclusion we get from that . . . namely, "in a parallel circuit . . . the SMALLEST RESISTANCE BRANCH DISSIPATES THE MOST POWER!" That's the opposite from series circuits isn't it? Another observation we can make is that total power is the sum of all the individual power dissipations in the circuit . . . and, as usual is also equal to $E_A \times I_T$. THIS FACT IS TRUE FOR ANY KIND OF CIRCUIT! (That is, total power equals the sum of all the individual power dissipations throughout the circuit).

INFORMATION

OK . . . here's another practice problem for parallel circuits.

REFERENCE & DATA



CHECKPOINTS

CHECKPOINT

Solve the circuit shown in column 2 for the following:

1. E_A = _____ v.
2. R_2 = _____ K ohms.
3. I_3 = _____ mA.
4. I_T = _____ mA.
5. P_{R_1} = _____ mW.
6. P_{R_2} = _____ mW.
7. P_{R_3} = _____ mW.
8. P_T = _____ mW.

ANSWERS:

1. **30 volts.**
2. **20K ohms**
3. **3 mA.**
4. **7.5 mA.**
5. **90 mW.**
6. **45 mW.**
7. **90 mW.**
8. **225 mW.**

Hope you did well on this. We'll think through it here so you can check your method of solution.

First . . . we know that E_A is going to be the same as the voltage across any of the branches. Since we have "2 knowns" about branch No. 1, we can solve for E_{R_1} easily. 3mA. x 10K = 30v. Hence, we know that E_A is 30 volts.

We can see that branch No. 2's current is half that of branch No. 1 . . . so we know that branch No. 2's resistance must be TWICE that of branch No. 1. This means that R_2 = 20 K ohms.

We know that branch No. 3's current must be the same as branch No. 1's . . . since it has the same E and R . . . thus, I_3 = 3 mA.

Total current for a parallel circuit must equal THE SUM OF THE BRANCH CURRENTS! This gives us 7.5 mA. for the total current.

The power dissipated by each branch resistance can be calculated simply by using the product of the branch E and the branch I. This gave us 90 mW. for branches No. 1 and No. 3, and 45 mW. for branch No. 2.

Total power could have been calculated either by $E_T \times I_T$ . . . OR, simply by adding up all the individual power dissipations. This yielded 225 mW. total power.

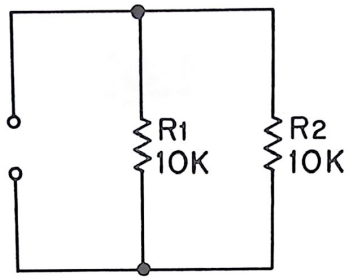
Finally, R total could have been calculated by $R_T = E_T/I_T$ . . . giving 30v/7.5 mA. = 4K ohms. Interesting that the total resistance for parallel circuit IS LESS THAN THE LEAST RESISTANCE BRANCH! The reason of course, is because each branch provides another current path that the source supplies current for . . . hence, the more current paths . . . the higher I_T . . . **and** $R_T = \frac{E_T}{I_T}$

This brings us to a VERY IMPORTANT FORMULA for parallel circuits. It is true that when you have enough "givens", you can solve for any parameter in a circuit, including R total. Sometimes, though, you will only know the resistor values in the circuit, and you want to be able to solve for the total resistance. The key formula to remember for parallel circuits for solving R_T is:

$$R_T = \frac{R_T \times R_2}{R_1 + R_2}$$

This is many times called "THE PRODUCT OVER THE SUM" formula. We won't try to explain all the mathematical derivations of this formula . . . but we do want you to be able to use it.

Try it on this problem!



CHECKPOINT

Use the "product over the sum" formula and solve for the total resistance of the circuit shown in the adjacent column.

R_T = _____ K ohms.

ANSWER:

R_T = 5K ohms.

Did it work for you? Here's an interesting fact to remember . . . whenever you have two EQUAL value resistors in parallel . . . the EQUIVALENT resistance of the two will be ONE HALF of either branch R. The reason is obvious. The total current will be twice that of a circuit with only one of the R's in it; thus, the same E divided by twice the I = ½ the R.

This can be carried to a further degree. If we have a parallel circuit with THREE EQUAL R BRANCHES . . . the total (or equivalent) resistance of the three branches will be equal to 1/3 any one of the branches. Again . . . you can see that a circuit with three equal branches will have three times the current of a single resistor circuit . . . with the same E applied.

We challenge you to draw a circuit having three 1K resistors in parallel and an E applied of 1 volt . . . and calculate the branch currents and I total . . . then use Ohm's Law and calculate R total. It should prove what we just told you . . . i.e., R_T will be 1/3rd that of one branch. What this all "boils down to" is: **In a parallel circuit with equal resistance branches . . . the equivalent total resistance of all these equal parallel branches will be one of the branch R's divided by the total number of equal R branches.** Hence, if we have five parallel 10K branches . . . R_T WOULD EQUAL 1/5th of 10K . . . or 2K ohms . . . and so on.

INFORMATION

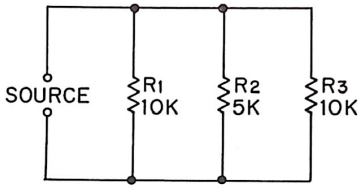
Let's show you how to use this to advantage . . . even in a circuit where NOT ALL the branches are the same value . . . but some of them are.

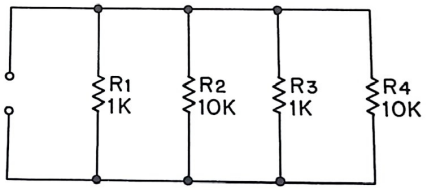
Look at the circuit in column 2, and follow our reasoning below.

If R_2 were not present . . . the total resistance of the circuit would be 5K . . . correct? Sure, two 10Ks in parallel equal an equivalent resistance of 5K . . . even when you work it out by the "product over the sum" formula. Now . . . here's a nifty trick. We CAN say that the equivalent total resistance of R_1 and R_3 in parallel IS 5K. Let's use the R_e (R equivalent) of R_1 & R_3 and combine it with R_2's resistance to get R total. HOW ABOUT THAT! We now can easily see the equivalent total resistance of R_2's 5K in parallel with R_1 & R_3's 5K will yield a circuit total resistance of 2.5K.

All we've said is this. You can combine equal resistance branches . . . using this technique, and then apply the product over the sum formula, or any other means, to solve for R_T. If R_2 had not been 5K (for convenience sake); then, you would have had to apply the product over the sum formula to find the final results (R total for circuit). In fact, let's try a problem where you must use your "tricky technique" of combining equal branches . . . plus the product over the sum formula to get the answer. Solve the problem at right for total resistance.

REFERENCE & DATA





CHECKPOINTS

CHECKPOINT

Solve for R_T for the circuit shown:

R_T = _____ K ohms.

ANSWER:

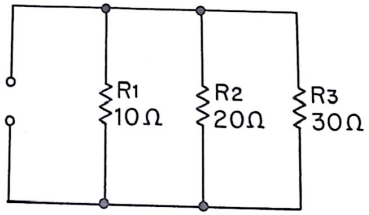
R_T = **0.45K ohms**

Here's the pattern of thinking you should have used:

1. *R_1 and R_3 are equal resistance branches whose equivalent resistance would equal 0.5K.*
2. *R_2 and R_4 are equal resistance branches whose equivalent resistance would equal 5K.*
3. *Total resistance will equal:*

   0.5K x 5K divided by 0.5K + 5K
   Giving: 2.5/5.5 = 0.45K

Now, let's suppose you had a circuit where none of the branches were equal . . . now what? All right . . . one approach that will always work is to use the product over the sum formula to solve any two of the branches . . . then take that equivalent resistance (called R_e) of the two branches just solved and work it with the next branch using the same formula. Look at the example in column 2.



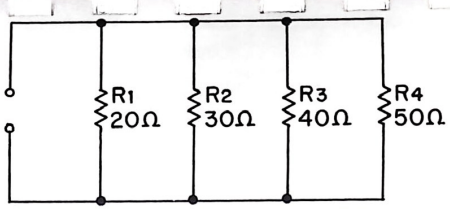
SOLUTION

Step 1: $\frac{R_1 \times R_2}{R_1 + R_2} = \frac{10 \times 20}{10 + 20} = 6.66\Omega$

Step 2: $\frac{Re \times R_3}{Re + R_3} = \frac{6.66 \times 30}{6.66 + 30} = \frac{199.8}{36.66} = 5.45\Omega$

R_T = **5.45Ω**

All right . . . you try this one!



CHECKPOINT

Solve for R_T of the circuit shown in column 2.
R_T = _____ ohms.

ANSWER:

R_T = **7.79 ohms**

You had to go through one more step than we did in our example didn't you? It should have worked the same though.

Let's interject a thought here. It may seem we've been devoting far too much time on this subject . . . when are we going to move on? Well, yes we are spending a lot of time here, but these things are basic—and you must grasp the basics fully before you can go on.

Now that we've shown you three basic methods for solving for total resistance in a parallel circuit . . .

1. Using Ohm's Law with known voltages and currents, etc.
2. The "PRODUCT OVER THE SUM" formula.
3. Combining equal resistance branches, where possible.

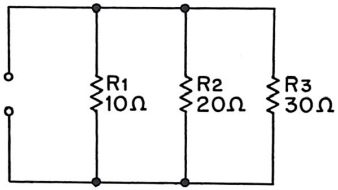
. . . we now want to show you just one more method . . . but it is a very handy one. Mathematically ALL THE METHODS USED could be traced back to the fact that current is inverse to resistance for any given E.

Here's the new method . . . which by the way is often referred to as . . . **The Assumed Voltage Method**. To show you how this works . . . let's look at our sample three branch circuit we used as an example earlier.

The steps for the **Assumed Voltage Method** of solution are as follows:

1. Assume a convenient value of E_A.
2. Solve for each branch current. (Many times this can be done in your head if the values are convenient.)
3. Solve for total current. (Simply add all the branch currents.)
4. Solve for R_T by using Ohm's Law. That is: E_A assumed divided by I_T Calculated on the basis of the assumed voltage.

This Assumed Voltage Method is particularly good where all the branches are of different value . . . and/or are "odd ball" values. The key is to assume a voltage which is convenient to divide into by each branch R to solve for branch currents.



Step 1: ASSUME 30V E_A
Step 2: I_1 = 3A; I_2 = 1.5A; I_3 = I_A
Step 3: I_T = 3 + 1.5 + 1 = 5.5A
Step 4: R_T = 30v/5.5A = 5.45Ω

INFORMATION

It's about time that we summarize the key things we've told you about parallel circuits. These are things you should remember for sure!

1. Voltage across all parallel components is the same.
2. Current through any given branch is inverse to that branch's resistance. (This means the smallest R branch has the most current . . . the highest branch R the least, etc.)
3. Total current equals the sum of the branch currents.
4. Total resistance is always LESS THAN THE LEAST BRANCH R.
5. The smallest resistance branch dissipates the most power. (And, the highest R branch, the least, etc.)
6. Total power equals the sum of all the individual power dissipations, and/or equals $E_A \times I_T$.
7. Ohm's Law can be used to solve parameters anytime you have enough knowns to use it.
8. Several methods for solving for R_T are: Ohm's Law; Product over the Sum formula; Equal branches trick; and the Assumed Voltage technique.

To bring into focus all the things that we've said about SERIES circuits and PARALLEL circuits . . . look at the ***COMPARISON CHART****. If you will study AND UNDERSTAND . . . NOT MEMORIZE these facts . . . you will be "money ahead" for the FCC exam.*

THE SERIES—PARALLEL CIRCUIT

The final circuit configuration we want to discuss is the Series-Parallel circuit. As the name implies . . . parts of this circuit have series elements and other parts of the circuit have parallel elements. Sometimes you hear this type circuit called a "combination" circuit. We'll use the term **series-parallel** circuit most of the time . . . and for convenience, we'll sometimes abbreviate it an "S-P" circuit.

You have already learned the most important concepts needed to analyze S-P circuits. The key here is to use the rules for series circuits in analyzing the portions of the circuit where elements are in series . . . and use the rules for parallel circuits for the parts of the circuit for which that is appropriate. To get the final results . . . you merely combine the results, as you will see in our next example.

REFERENCE & DATA

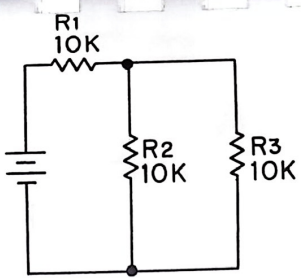
COMPARISON CHART FOR SERIES & PARALLEL CIRCUITS

Item being considered	Series Ckt.	Parallel Ckt.
Circuit connection	Components connected "end-to-end".	Components connected "side-by-side".
Total Resistance	Sum of all resistances	Less than least branch resistance
Voltage Distribution	E_T = sum of all individual voltage drops; and largest R drops most voltage.	Voltage is the same across all parallel components. (= E_A)
Current Distribution	Same current through all components in series (≡ I_T)	Current splits or divides at "branching points"; inverse to branch R. Total current equals SUM OF ALL BRANCH CURRENTS.
Power Distribution	Largest R dissipates most power. Total P equals sum of individual P dissipations or $E_A \times I_T$.	Smallest R dissipates most power. Total power = sum of all individual power dissipations, or, $E_A \times I_T$.
CIRCUIT COMMON FACTOR	Current	Voltage

Look at the three-resistor S-P circuit shown in the next column, and follow the observations below:

1. R_2 and R_3 are in parallel WITH EACH OTHER . . . since their ends are connected . . . as it were . . . "side-by-side" and they obviously have the same voltage "across" them.

2. R_1 is in series WITH THE PARALLEL COMBINATION OF R_2 and R_3 . . . but not with either one alone . . . since the current through R_1 is really the sum of the currents through R_2 and R_3.



CHECKPOINT

What is the total resistance of the circuit?

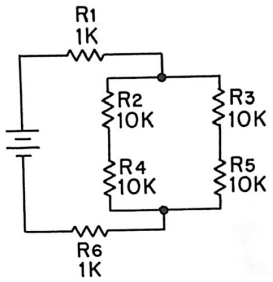
_____ K ohms.

ANSWER:

R_T = **15K ohms**

Did you have the right answer? The basic logic here is that since R_2 and R_3 are in parallel with each other . . . and are equal in value . . . their equivalent combined resistance must be 5K ohms. (remember our "tricky" method for equal values of R in parallel?) Okay . . . this R_e of 5K is effectively in series with R_1's 10K . . . hence total resistance = 15K ohms. See . . . we've got a slightly different animal than a simple series circuit, where R_T would equal the sum of all the resistors in the circuit . . . or, a simple parallel circuit, where total resistance would be less than the least resistance branch. For S-P circuits . . . you must analyze the parallel portions . . . where the series portions combine with the parallel portions of the circuit.

Try this S-P circuit!



CHECKPOINT

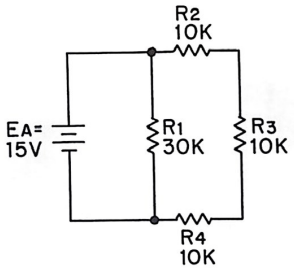
Find R total R_T = _____ k ohms.

ANSWER:

R_T = **12K ohms.**

Are you "getting the hang" of how to combine and analyze? Hope so!

Alright! Here's one final brain teaser so you can practice using Ohm's Law and the rules for solving series-parallel circuits.



CHECKPOINT

Refer to the circuit at left, and find the following parameters:

1. R_T = _____ K ohms.
2. I_1 = _____ mA.
3. I_2 = _____ mA.
4. I_T = _____ mA.
5. E_{R_3} = _____ v.
6. E_{R_1} = _____ v.
7. P_{R_1} = _____ mW.
8. P_{R_3} = _____ mW.
9. P_T = _____ mW.

ANSWERS:

1. R_T = 15K ohms
2. I_1 = 0.5 mA.
3. I_2 = 0.5 mA.
4. I_T = 1.0 mA.
5. E_{R_3} = 5 volts
6. E_{R_1} = 15 volts
7. P_{R_1} = 7.5 mW.
8. P_{R_3} = 2.5 mW.
9. P_T = 15.0 mW.

If you had any trouble with that problem, go back and review the pertinent information regarding series, parallel and S-P circuits until you understand the answers.

AC VOLTAGES AND CURRENTS

Now that you've had quite a bit of practice using "glorified Ohm's Law" circuit analysis of DC circuits . . . it's time to begin learning how this same approach can be used for AC circuit analysis.

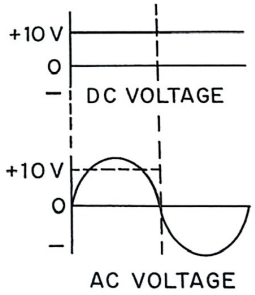
Let's quickly review the difference between DC and AC. Look at the illustrations of DC voltage and AC voltage.

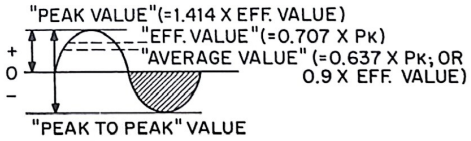
Observe that the DC voltage is at one level . . . and of one polarity (in this case +). The AC voltage is continuously changing level (amplitude), and alternately is going in a positive direction . . . then a negative direction (polarity).

As a radio amateur . . . you will be working with both DC voltages and currents from DC sources and with AC voltages and currents from AC sources. A car battery is an example of a DC source. The outlet in your home is an example of a 60 Hz, AC source.

Probably the first thing we should do is to familiarize you with the important values of a "sine-wave" AC voltage . . . since this can appear on your FCC test . . . and besides, it will make you a better technician if you learn it.

Study the sketch of the various sine-wave values . . . then we'll discuss some of the meanings.





The sketch shows one "cycle" (Hertz) of a sine-wave AC voltage. The reason it is sometimes called a sine-wave is that its value or amplitude at any given instant of time during the cycle can be computed from the mathematical function called the "sine". For example, if we consider the cycle starting at 0, at 0 degrees . . . the sine of an angle of 0 degrees is equal to zero. Since the complete cycle takes 360 degrees . . . then you can see from the diagram that after 90 degrees (1/4th cycle), the amplitude is at peak value . . . and sure enough . . . the sine of 90 degrees equals 1 (maximum value) . . . and so on.

Okay . . . let's discuss some of the "values" called out on the sketch.

1. **Peak value** is called that for obvious reasons. Peak value is the highest amplitude the sine-wave reaches . . . either during the positive half-cycle (called an "alternation"), or during the negative alternation.

2. **Peak-to-peak value** is also obvious . . . and of course equals twice the peak value.

3. **Effective value** (sometimes called RMS value) is a very important value to know about. To clarify it a little . . . let's assume that we were to apply 10 volts of **DC** voltage to a 1K resistor. How much power would this resistor dissipate in the form of heat? Well, a 1K resistor with 10 volts across it must be passing 10 mA. of current . . . thus the power equals 10mA x 10v = 100 mW of power dissipation.

How does this resistor dissipate that 10 mW of power? Basically the power is dissipated in the form of heat. If I were to apply an AC voltage whose peak value were 10 volts . . . would this cause the resistor to dissipate as much heat (or power)? Of course not! The reason is that the AC sine-wave is only at peak value for a small portion of the time of the cycle . . . hence its EFFECTIVE value, as far as the resistor is concerned is less than the peak value. In fact, it can be mathematically proven that if I applied a sine-wave voltage who's peak value was 1.414 times the 10 volts . . . or 14.14 volts . . . THEN, the effective heating effect on the resistor would be the same as the 10 volts DC. Interestingly enough . . . 0.707 times 14.14 turns out to be 10. EFFECTIVE VALUE = 0.707 x peak value . . . and PEAK VALUE = 1.414 x effective value. Remember these two "magic numbers" . . . they are used a lot.

You might ask . . . how come the effective value of the sine-wave is not the mathematical average amplitude? The answer lies in the waveshape. Because the amplitude is higher than the average level FOR A LONGER TIME than it is below the average level, then the EFFECTIVE value has to be higher than the mathematical average of each alternation.

We probably don't need to dwell on this subject any longer. Let us simply say that it is important that you learn the relative values "called out" on our diagram, and remember the "magic numbers" that show these relationships.

Try the checkpoint to see if you know these important relationships.

CHECKPOINT

1. If a sine-wave has a peak-to-peak amplitude of 30 volts . . . what is its peak value? _____ volts.

2. If the peak value of an AC voltage is 28.28 volts . . . what is its EFFECTIVE (or rms) value? _____ volts.

3. A sine-wave voltage has an effective value of 120 volts . . . what is its peak value? _____ volts.

4. If the effective value of an AC voltage is 100 volts . . . what is its "average" value? _____ volts.

ANSWERS:

1. **15 volts**
2. **20 volts**
3. **169.2 volts**
4. **90 volts**

INFORMATION

How did you do? If you missed any of these . . . better review . . . .

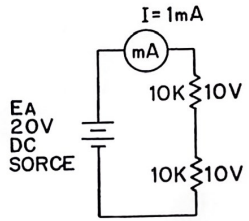
As you may have gathered from the discussion we just finished . . . probably the most important value with reference to sine-wave AC voltages and currents is the EFFECTIVE value. Be aware that virtually all AC measurement instruments, such as voltmeters and current meters are designed so that they measure **effective** value. Some do have provision for measuring peak or peak-to-peak . . . however, these are special scales on the instrument. When you use an AC voltmeter or current meter . . . what you read is **rms**, or **effective** value, unless otherwise stipulated.

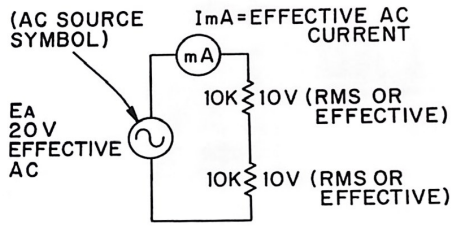
Now, you may be wondering . . . can I use Ohm's Law to analyze AC circuits, the same way I do for analyzing DC circuits. In a broad sense, the answer is YES! For **purely resistive** circuits . . . you use the same exact procedures when using the EFFECTIVE VALUES of voltage or current. In other words . . . for all those problems we had you solve for series circuits, parallel circuits, and S-P circuits . . . if the values of voltage and/or current were given as **effective** values . . . your answers would be exactly the same as for DC. If the values were stated as **peak** values . . . you would have simply had to convert them to effective values by multiplying by 0.707 . . . and then plug the effective values into the formulas. The same rules apply to a resistive circuit with AC applied, as with DC applied. That simply means that the rules for current distribution, voltage distribution, etc. hold.

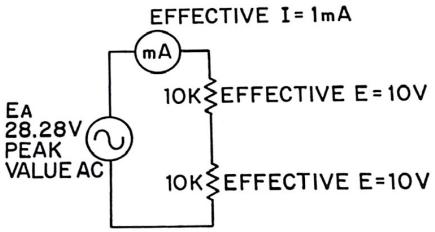
Rather than waste your time working more problems with purely resistive circuits . . . let's move on now and begin to consider some components and circuits that operate a little differently with AC applied than does the simple resistor element.

Remember our old friend **Frequency**? Well, the elements we are about to discuss show different oppositions to current flow for different frequencies of AC applied to them. Because of this . . . these components open up a whole new "vista" of controlling electron flow in electronic circuits.

REFERENCE & DATA



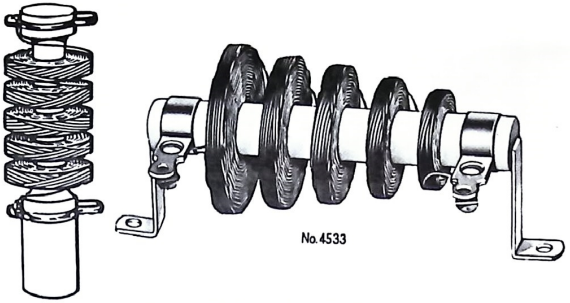




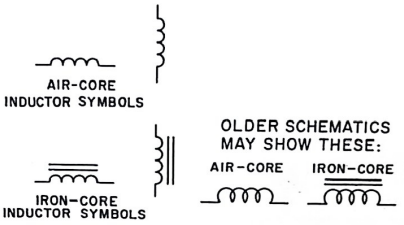
CHECKPOINTS

INDUCTANCE AND X_L

The **inductor**, or coil, is a very important member of the electronic component family. Inductors are used in power supplies to help smooth the "pulsating DC" we introduced you to way back in the Novice chapter. They also find use in Audio Frequency circuits as "filtering" elements. At "power" frequencies and audio frequencies, these coils are usually of the **iron-core** type. Inductors of the **air-core** type are used at the higher RF (radio frequency) frequencies. Here, they may be used as coupling or decoupling elements, or as tuning elements . . . such as in your TV set, or radio . . . as part of the channel- or station-selecting portions of the circuit. Look at the schematic symbols for the air-core (RF) coil, and iron-core types shown in the next column.



Courtesy of Bell Industries, J. W. Miller Div.



Remember we told you earlier that an inductor "stores" electrical energy in the form of an electromagnetic field. You really don't need to comprehend the physics of the situation. Just be aware that anytime current passes through the wire of an inductor, an electromagnetic field is set up . . . when the current is taken away . . . the field collapses. Whenever a conductor (or wire) is in the presence of a changing magnetic field . . . an interesting thing happens. A voltage is **induced** into the wire . . . and if there is a complete path for current, an **induced** current will be caused to flow. It turns out that the emf induced is called a **back emf** . . . and opposes the change in current that caused the field which induced it in the first place. All that this "double-talk" means is this: AN INDUCTOR OPPOSES ANY CHANGE IN CURRENT THROUGH ITSELF! If the current is trying to increase . . . the property of the inductor (because of back emf) is to oppose this increase . . . if current is trying to decrease through the coil . . . the induced emf will try to maintain the current and keep it from decreasing. This oppostion to varying current (AC) offered by an inductor is called **inductive reactance.**

As you might reason . . . the faster the rate of change of current . . . the greater the opposition the coil will show to this change . . . therefore, the greater the coil's **Inductive Reactance.** Also . . . the greater the inductance of the coil . . . the greater the inductive reactance.

This **inductive reactance** is computed in ohms . . . since it is an opposition to AC current flow. So far we've said that **Inductive Reactance** is higher if the rate-of-change of current is higher . . . and, that, the greater the inductance of the coil . . . the greater will be the Inductive Reactance. Let's distill all this into a formula you need to know. Before we do . . . let's give you the symbols for inductance (in Henrys) and inductive reactance (in Ohms). Look at column 2.

The inductance of a coil depends on the number of turns of wire . . . the diameter of the coil . . . and the magnetic properties of the core of the coil. More turns means higher inductance. Bigger diameter means more inductance. And, the higher the magnetic property of the core . . . the more the inductance.

L = symbol for Inductance
Basic unit of Inductance is the HENRY

X_L = symbol for Inductive Reactance
Basic unit of Inductive Reactance is the OHM

INFORMATION

Now for the formula for X_L.

When you think about it . . . that formula makes a lot of sense. As you recall . . . we said that the faster the rate of change of current . . . the higher the opposition, or X_L That obviously relates directly to the frequency. Look at the diagram of two frequencies . . . as you can see, the higher the frequency . . . the faster the rate of change of voltage and/or current . . . so "sure enough" if frequency is doubled . . . X_L will double.

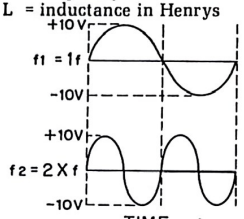
The same DIRECT relationship is true regarding inductance and inductive reactance. If we double the inductance of a coil . . . it will give double the X_L for any given frequency.

Try the little X_L problem at this checkpoint.

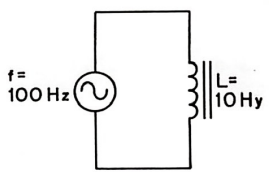
REFERENCE & DATA

$X_L = 2\pi fL$

Where:
X_L = inductive reactance in ohms
2 = 6.28
f = frequency in Hertz
L = inductance in Henrys



CHECKPOINTS



CHECKPOINT

Refer to the diagram above and solve for the inductive reactance of the coil.

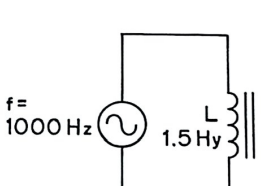
X_L = _____ ohms.

ANSWER:
X_L = 6,280 ohms

Did you use the X_L formula correctly? In this case the way you should have done it is:

1. *Write down the formula:*
   $X_L = 2\pi fL$
2. *Then substitute the values:*
   $X_L = 6.28 \times 100 \times 10 = 6{,}280$ ohms.

To see if you understand the concept of how inductive reactance changes with frequency and inductance values . . . try the next checkpoint.



CHECKPOINT

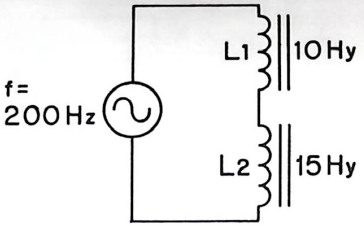
1. Solve for X_L for the circuit shown in column 2.
   X_L = _____ ohms.
2. If the frequency were doubled and the inductance were the same value, what would be the X_L? _____ ohms.
3. If the frequency were cut to 1/2 and the inductance were doubled, what would be the resultant X_L?
   X_L = _____ ohms.
4. If the frequency were doubled and the inductance tripled . . . the resultant X_L would be _____ times as great as the original circuit shown.

ANSWERS:
1. **9,420 ohms**
2. **18,840 ohms**
3. **9,420 ohms**
4. **6 times**

As you can see from the results on the checkpoint . . . Inductive Reactance is DIRECTLY PROPORTIONAL TO FREQUENCY AND TO INDUCTANCE.

What happens if two inductors are connected in series? The answer is simply . . . INDUCTANCES IN SERIES ADD LIKE RESISTORS IN SERIES. This means if a circuit has two 10 henry coils in series . . . the total circuit inductance will be 20 henries. What about the inductive reactance? Since X_L is directly proportional to L . . . then two 10 henry coils in series will exhibit a total X_L related to 20 henries. Let's say right here: REACTANCES IN SERIES ADD LIKE RESISTANCES IN SERIES. This means if I had a coil with a reactance of 1000 ohms in series with a coil with a reactance of 2000 ohms . . . the total inductive reactance would be 3000 ohms.

Try the short Checkpoint!



CHECKPOINT

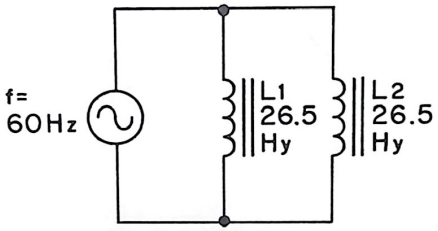
1. The inductive reactance of L_1 is _____ ohms.
2. The X_L of L_2 is _____ ohms.
3. The total circuit inductive reactance (X_{LT}) is _____ ohms.
4. The total inductance in the circuit is _____ Henries.

ANSWERS:
1. **12,560 ohms**
2. **18,840 ohms**
3. **31,400 ohms**
4. **25 Henries**

As you probably have already guessed . . . Inductors in parallel add like resistors in parallel. This means that if two 5 Henry inductors are in parallel . . . the net effective total circuit inductance would be one half of that . . . or 2.5 Henries. (You can solve it by the product-over-the-sum formula, just like you did for resistors) Obviously, the Inductive Reactance is directly related to the inductance . . . hence would be less than the least branch X_L.

For inductors in parallel then, you can use the product-over- the-sum formula to find total inductance . . . and you can also use this same approach with the reactances to solve for total inductive reactance.

Give this checkpoint a try!



CHECKPOINT

Note: Round off to the nearest K ohm for all your calculations.

1. X_L for L_1 = _____ ohms.
2. X_L for L_2 = _____ ohms.
3. X_{LT} = _____ ohms.
4. Total Inductance = _____ Henries

ANSWERS:
1. **10K ohms** (rounded from 9,985.2 ohms)
2. **10K ohms** (rounded)
3. **5 K ohms** (rounded)
4. **13.25 Henries**

As we already implied . . . equal inductors in parallel can be calculated by the same "tricky" method of equal resistors in parallel. That is, divide the number of equal valued branches into one-branch values . . . and you'll get the resultant equivalent total inductance (or reactance) of these equal branches.

INFORMATION

So far we've talked about inductances combined with other inductances . . . and discussed how to find total inductance and how to find total inductive reactance. Let's move ahead now into a "generalized" understanding of what happens when you combine resistors and inductors in one circuit. We do not need to go into "deep AC theory" and mathematics to give you the concepts you need . . . so we won't!

The fact that an inductor "opposes a change in current" causes the current through an inductor to LAG BEHIND THE VOLTAGE ACROSS THE INDUCTOR by 1/4th cycle . . . which is 90 degrees. A whole cycle represent 360 degrees, as you already know. Now a crutch to help you remember the fact that current LAGS voltage in an inductor . . . remember the man's name "ELI". The E in the name stands for the voltage . . . the L stands for the inductance . . . and the I stands for current. So to use this "crutch" . . . think: E comes before I in an inductor (L). As you can see with the name ELI . . . the E is before the I!

Because maximum current does not occur at the same time maximum voltage does . . . we say that the two are ***out of phase****. In this case . . . they are out of phase by approximately 90 degrees. If the inductor were perfect . . . and only had inductance with no resistance . . . it would be 90 degrees . . . but since there is some resistance in the wire of the coil . . . the phase difference is really less than 90 degrees for a practical coil.*

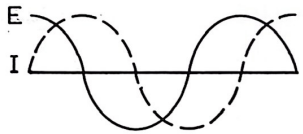
Look at one way this 90 degree out of phase condition can be represented (showing the phase difference between E and I in an inductor). Notice that when one parameter is at maximum amplitude . . . the other is at zero . . . and vice versa.

THE RL CIRCUIT

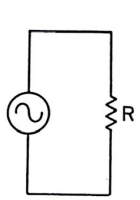
Now let's think about what will happen when we put a resistor and an inductor together in a single circuit. Look at the schematic in column 2, and follow our reasoning below:

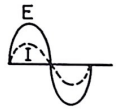
We haven't really said it before, but in a purely resistive circuit, the voltage and current are in phase. This means that when E across a resistor is maximum . . . the current through it is also at maximum. We have just finished telling you that in an inductor, there is approximately 90 degrees phase difference between the E_L and the I_L. When we combine the two elements . . . logic tells us that the resultant total circuit voltage (E_T or E_A) will NOT be perfectly in phase with total circuit current (I_T) since the circuit is not purely resistive . . . **nor** will they be 90 degrees out of phase . . . since the circuit is not purely inductive. The result will be the E_T and I_T are out of phase by some angle between 0 degrees and 90 degrees. Does that make sense? Sure it does . . . and that is actually what takes place.

REFERENCE & DATA



VOLTAGE AND CURRENT RELATIONSHIP IN AN INDUCTOR





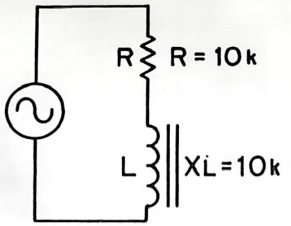
E IS MAX. WHEN
I IS MAX.
AND
E IS MIN. WHEN
I IS MIN.

CHECKPOINTS

Now, what determines how "out of phase" they are? (Another way of saying this is "what will the phase-angle of the circuit be?)

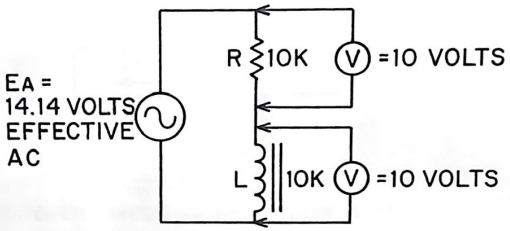
Let's reason our way through to an answer for that last question in two steps. First for a series RL circuit . . . then, for a parallel RL circuit.

Look at the sample series RL circuit. Here is a case where the resistance is 10K ohms, and the inductive reactance is 10K ohms.

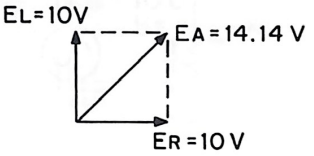


Since the R and the L are having an equal effect on the circuit current . . . can you guess what the phase angle will be? If you said 45 degrees . . . you were "right on"! Now let's suppose that the inductance were doubled . . . so that means the X_L would double to 20K. Now, which element is having the most control of the circuit current . . . the resistor, or the inductor?

Right! The inductor. Would you guess that the circuit phase angle would now get closer to 0 degrees (purely resistive) . . . or to 90 degrees (purely inductive)? The answer is obviously . . . the circuit becomes "more like" a purely inductive circuit . . . so the phase angle would now be greater than 45 degrees (where R and X_L were equal) . . . but less than 90 degrees (which would have to be 100% inductive) . . . Are you getting the idea? FOR SERIES CIRCUITS CONTAINING RESISTORS AND REACTANCES . . . THE ELEMENT WITH THE LARGEST OHMIC VALUE HAS THE MOST CONTROL. This means if the circuit had a resistor whose value is 10 times the reactance of the reactive component . . . the circuit would act almost like a purely resistive circuit. If the reverse were true . . . the circuit would act almost like a purely reactive circuit.



One other interesting fact regarding RL circuits . . . then we'll move on to the parallel RL circuit. Since the voltage across the coil is out of phase with the current through it . . . and the current THROUGHOUT a series circuit is the same current . . . this means the voltage drop across the coil is out of phase with the voltage drop across the resistor . . . SO YOU CAN **NOT** JUST ADD THE TWO VOLTAGE DROPS ARITHMETICALLY TO FIND E APPLIED. They must be added **vectorially**.



INFORMATION

Vectorially is a big word. You don't need to worry about it because we are not going to go into a lot of vector math . . . but simply want you to get a concept.

If two fellows were tugging on two ropes that are tied at the other ends to a common "load" . . . and the two fellows are tugging with 10 pounds force each . . . but the ropes were aimed in directions that were 90 degrees apart, the resultant force on the "common load" point would not be 20 pounds . . . nor 10 pounds . . . but 14.14 pounds . . . similar in concept to our example of the voltage drops. You get the idea . . . the resultant is not as large as the sum of the two individual vectors . . . but is greater than the largest one of the vectors. So for a series RL circuit, the applied voltage does not equal the simple sum of the two voltage drops . . . but the **vector sum.**

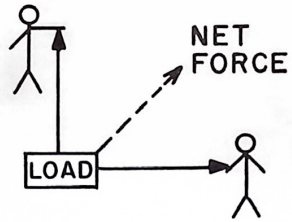
Time to consider some facts about a **parallel** RL circuit. As we have already hinted . . . the component in an RL circuit that has the most control over the circuit current is the one which has the greatest effect on the resultant phase angle between E applied and circuit total current. Look at our simple parallel RL circuit diagram—which element do you think is having the greatest effect on the circuit phase angle? If you said the resistor in this case, you were correct. Why? Because there is more "resistive branch current", than there is "inductive branch current". What this says to us is that in PARALLEL RL CIRCUITS, THE BRANCH WITH THE SMALLEST OHMIC VALUE HAS THE MOST EFFECT! Notice this is just the opposite from the series RL circuit, where, the largest ohmic value component has the greatest effect on the circuit.

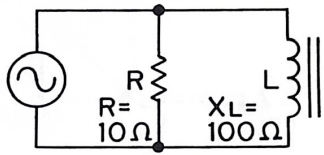
In parallel RL circuits, the voltage is the same across all parallel branches . . . and, of course is equal to E applied . . . so the voltages across all the branches are in phase . . . BUT THE CURRENTS THROUGH THE RESISTIVE AND INDUCTIVE BRANCHES ARE OUT OF PHASE. This means that the total circuit current, (IT) must not be equal to the simple sum of all the branch currents, like they were for DC circuits . . . or purely resistive AC circuits . . . but total current is the **vector** *sum of the branch currents.*

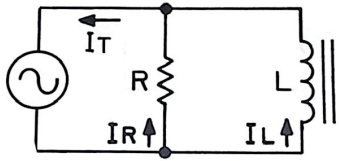
If the X_L branch = 10K ohms, and the R branch = 10K ohms, then the circuit phase-angle will be 45 degrees. (Each branch current has an equal influence on IT). If X_L is smaller than R . . . then the circuit will tend to act "more inductive" . . . since IL will be greater than IR. Of course, if R is smaller than X_L, the opposite is true.

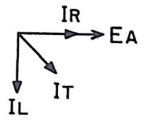
Let's see if you have the general idea of series and parallel RL circuits. Try the Checkpoint!

REFERENCE & DATA









CHECKPOINTS

CHECKPOINT:

1. For a **series** RL circuit with a resistor of 20K and an inductor whose reactance is 30K, the phase angle between EA and IT would be (more than 45 degrees; less than 45 degrees)?_____.

2. For a **parallel** RL circuit with a resistor of 20K and an inductor whose reactance is 30K, the phase angle between EA and IT would be (more than 45 degrees; less than 45 degrees? _____.

ANSWERS:

1. **More than 45 degrees.**
2. **Less than 45 degrees.**

CAPACITANCE AND X_C

Time to move on to our next reactive component . . . that is, one which shows different oppositions to different frequencies of AC. As you may have guessed, the one we'll look at now is the **capacitor**. The capacitor is also a very important member of the electronic component family. It finds application in power supply filter circuits, coupling circuits between electronic stages (such as amplifier stages), coupling circuits in oscillators, "decoupling" circuits of all kinds, timing circuits and in tuning circuits.

Recall the symbol for a fixed capacitor?

A variable capacitor uses this symbol:

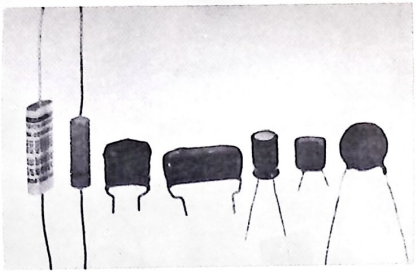
Remember that the key feature of the capacitor was that it opposed a change in voltage and that it stored electrical energy in the form of an "electric field" between the plates.

To refresh your memory as to the action of a capacitor in charging and discharging, (gaining and excess of electrons on one plate with respect to the other . . . and losing this electrical imbalance between the plates) . . . look at the diagrams in column 2.

When switch No. 1 is closed . . . the capacitor "charges". Electrons move from the negative side of the source . . . through R1 . . . and onto the bottom plate of the capacitor. The "electric field" between the bottom plate (which is now negative due to excess electrons) and the top plate "moves" electrons from the top plate to the positive side of the source. The result is that the capacitor becomes "charged". Electrons will continue to move and "charge" the capacitor until the potential difference between the plates equals E applied. After that no current (or electrons) will flow because the capacitor voltage (acquired through charging) is "series OPPOSING" the source voltage, and is of equal value. So no current flow, once the capacitor is charged. In effect, once the capacitor is charged . . . it BLOCKS DC.

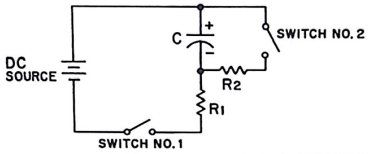
When switch No. 1 is opened and switch No. 2 closed . . . the charged capacitor has a "discharge" path. That is, the excess electrons on the bottom plate have a path whereby they may travel through R_2 and switch No. 2 to the top plate which has a deficiency of electrons. Electrons will move until the "plates are balanced equally", and E_C = 0 volts.

When the plates of the capacitor have reached this point of "electrical balance" and are electrically at the same potential . . . we say the capacitor is "discharged".

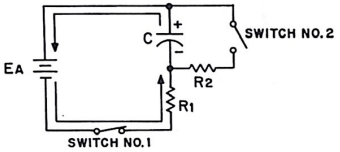


FIXED CAPACITOR SYMBOL

OR VARIABLE CAPACITOR SYMBOLS

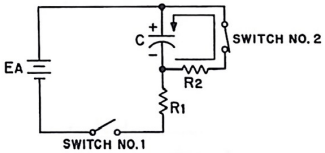


OPEN CIRCUIT—NO ELECTRON FLOW



CHARGE ACTION

Switch No. 1 Closed—Electrons move through circuit until E_C = E_A charging the capacitor. Bottom plate has excess of electrons—top plate has deficiency.



DISCHARGE ACTION

S No. 1 open; S No. 2 closed—Excess electrons on bottom plate move through R-2 and S-2 to top plate until bottom and top plates are at same potential E_C = 0 volts.

INFORMATION

A very interesting point regarding the charging and discharging of the capacitor is that the "charge or discharge" current must flow in order to change the potential between the plates . . . that is . . . current "leads" voltage changes on a capacitor. Remember our old friend "ELI" for inductors. Now we want to complete the "crutch" for you. REMEMBER THE SENTENCE . . . **"ELI THE ICE MAN"**. Interpreting the "crutch" sentence . . . **E Leads I for an inductor and I Leads E for a capacitor.** In other words . . . E is before I in our crutch word ELI (where L stands for inductance); and I is before E in our crutch word ICE (where C stands for capacitance).

In our charge and discharge discussion, we showed a fixed DC voltage source. Once the capacitor charged to the source voltage, there was no more charging current in the circuit. (No more current flow). Now . . . if we were to continuously vary the source voltage . . . guess what would happen. You're right . . . there would be a constant flow of charging and discharging current as the capacitor attempted to charge to the source voltage and discharge, as appropriate. In effect, that is what happens when AC is applied to a circuit with capacitance in it. Look at the diagram at the right.

Note two things from the diagram.

1. *Current continues to flow as long as the source voltage is changing . . . thus even though a capacitor BLOCKS DC . . . it effectively PASSES AC!*

2. *The current and voltage are 90 degrees out of phase for the capacitor . . . with current LEADING voltage. (Our old crutch . . . "ICE", I before E.)*

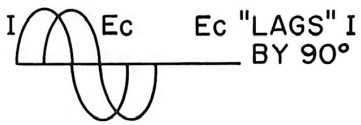
Before we move on to look at series and parallel RC circuits in the same manner as we studied series and parallel RL circuits, let's discuss total capacitance of capacitors in series and parallel. And the resultant total capacitive reactances, in series and parallel.

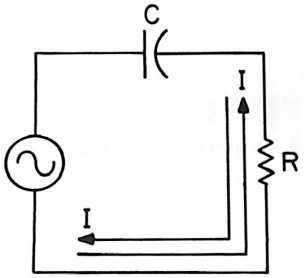
To help you understand this, we'd better tell you what PHYSICAL factors of a capacitor determine its capacitance value. You recall that **one farad** of capacitance was that amount of capacitance which would store **one coulomb** (6.28×10^{18} electrons) of charge with **one volt** applied. The THREE **physical** factors which determine the amount of capacitance for any given capacitor are:

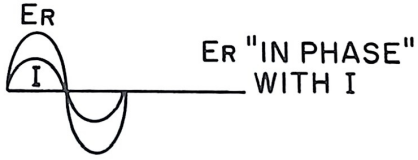
1. Total area of plates facing each other.
2. Spacing between the plates (dielectric thickness).
3. Characteristic of the material, or dielectric between the plates.

Some examples of dielectric materials commonly used are: air, mica, waxed paper . . . and other non-conductive materials.

REFERENCE & DATA







CHECKPOINTS

Logic tells us that the more area the plates have . . . the greater the amount of charge they will store . . . AND THAT IS CORRECT! Logic also tells us that the farther apart the plates are from each other . . . the less effect the electrical charge on it will have on the other plate's electrical condition. Again, this is true . . . so . . . the thicker the dielectric (bigger the spacing between plates), the lower will be the capacitance.

So far we have concluded; the greater the surface area of the plates facing each other . . . the higher the capacitance value and the wider the spacing between plates . . . the lower the capacitance value. The final item then, is the characteristic of the dielectric (insulating) material between the plates. This characteristic is defined by a term called **the dielectric constant.** Air has a dielectric constant of 1. Mica has a dielectric constant (K) of about 5; Glass about 7-8, etc. The rule here is . . . the higher the dielectric constant . . . the greater the capacitance. If all other factors were the same (plate area and spacing), and capacitor No. 2 used a material with a K twice that of capacitor No. 1 . . . Capacitor No. 2 would have a capacitance twice that of No. 1. Get the idea? Try the checkpoint.

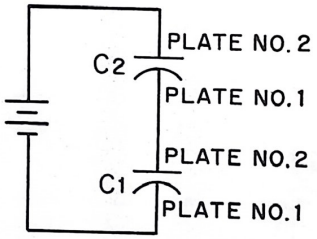
CHECKPOINT:

1. If capacitor No. 2 has three times the plate area of capacitor No. 1 . . . and No. 2's dielectric constant is 1/3rd that of No. 1 . . . is the capacitance of No. 2 (three times; the same as; or, 1/3rd that) of No. 1?

ANSWER:
1. **The same.** (Assuming the spacing were the same for both C's.)

Summarizing the above, we can say that the capacitor's value is directly proportional to its plate area and dielectric constant . . . and inversely proportional to the plate spacing.

What happens to the total capacitance when two capacitors are connected in series as shown in the drawing?



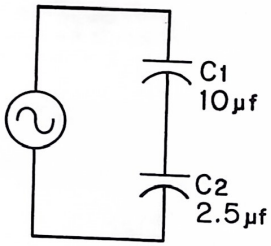
Notice that we have numbered the plates for reference purposes. Plate No. 1 (on C_1) is electrically connected to the negative side of the source. Plate No. 2 on C_1 is electrically the same (connected by conductor) as Plate No. 1 of C_2. Plate No. 2 of C_2 is electrically connected to the positive side of the source . . . hence the same potential as the positive side of the source. Let's pretend you're the source . . . looking at this circuit. The negative side of the source sees the "plate area" of plate No. 1 on C_1. The positive side of the source "sees the plate area of plate No. 2 of C_2 . . . but between the negative side of the source and the positive side of the source we see TWO thicknesses of dielectric material. In effect then the source sees the plate area of one capacitor, but with twice the dielectric thickness or plate spacing . . . HENCE THE TOTAL CAPACITANCE OF CAPACITORS IN SERIES IS LESS THAN THE LEAST CAPACITOR IN SERIES. In fact, we can use our "old magic" **product-over-the sum** formula to find C_T. Recall, the formula? Solving for total capacitance of two capacitors in series, it would read:

$$C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

CHECKPOINT:

What is the total capacitance of the circuit shown below?

C_T = _____ mfd.



ANSWER:
2 microfarads.

INFORMATION

As a reminder, let's mention that because a farad is a huge amount of capacitance . . . (a capacitor with this value might be the physical size of a small room) . . . capacitors generally come in values of micro farads (millionths of a farad); and micro-micro farads (trillionths of a farad). A more modern term for the later is "pico farads" . . . meaning the same thing. A 10 microfarad capacitor is normally written as 10 uf or 10 mfd. A 10 micro-micro farad (sometimes written uuf) can be found frequently written as 10 pf (for pico farad).

O.K. We've seen that capacitors in series add like resistors in parallel.

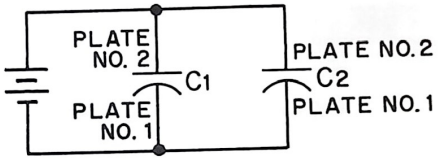
As you might already have anticipated . . . capacitors in parallel, add like resistances in series. This means that if I have a 10 uf capacitor in parallel with another 10 uf capacitor . . . the total capacitance of the circuit is 20 uf. Look at the circuit in column 2, and let's play our little game of pretending we are the source again. Now, the source sees the following;

1. *The negative side of the source sees C_1's plate No. 1 plate area AND C_2's plate No. 1 plate area.*
2. *The positive side of the source sees C_1's No. 2 plate area PLUS C_2's plate No. 2 area.*
3. *The spacing between all these plate areas is effectively ONLY ONE DIELECTRIC THICKNESS.*

Therefore, following the concept mentioned earlier that the capacitance is directly related to plate area and inversely related to the thickness of the dielectric . . . it is obvious that C total will be the sum of the capacitances. (We have twice the plate area and the other two factors are the same: namely, spacing between plates and dielectric constant.)

Try the checkpoint!

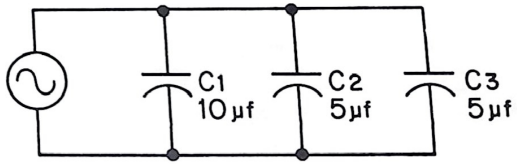
REFERENCE & DATA



CHECKPOINTS

CHECKPOINT:

What is the total capacitance in the circuit shown?



ANSWER:
C_T = 20 uf (10 + 5 + 5)

As you can see . . . you simply add up the values of all the capacitances in parallel to get the total capacitance. So, summarizing: CAPACITANCES IN SERIES ADD LIKE RESISTORS IN PARALLEL . . . CAPACITANCES IN PARALLEL ADD LIKE RESISTORS IN SERIES! (Just the opposite from the way finding total inductance works . . . right? Right!)

Now we come to an interesting subject regarding capacitors and AC. The subject is **reactance.** *Let's try to "Logic our way" through the way a capacitor opposes* AC current, *and see if we can come up with the "capacitive reactance" formula.*

Step 1: Since the amount of charge current that will flow in a circuit is directly related to how much capacitance the capacitor has . . . it is reasonable to assume that the larger the capacitance value, the more charge current will flow in order to charge that capacitor to E applied. Since, the larger the current flow for a given E applied . . . the lower the opposition to current flow must be . . . then we can deduct that LARGE C MEANS LOW OPPOSITION (or capacitive reactance); SMALL C MEANS HIGHER REACTANCE. In other words . . . CAPACITIVE REACTANCE IS INVERSELY PROPORTIONAL TO CAPACITANCE. This is true . . . so mark that down in your "biological memory bank" (your brain) and make notes alongside.

Step 2: The higher the frequency of AC applied to a capacitor . . . the faster it must charge and discharge in order to follow E applied . . . hence . . . more electron flow in less time means effectively . . . less opposition to current flow must be evidenced. Our deduction here is: THE HIGHER THE FREQUENCY OF AC APPLIED . . . THE LOWER THE CAPACITIVE REACTANCE (or opposition to AC current flow).

Step 3: Without going into deep mathematical derivations . . . we can logically deduce from the above statements that **Capacitive Reactance** is inversely related to both frequency and to capacitance.

It turns out, then, that the formula for capacitive reactance (symbolized by the term X_C . . . where X means reactance, and the subscript C indicates it is capacitive reactance is:

$$X_C \text{ (in ohms)} = \frac{1}{2\pi fC}$$

Where: $2\pi = 6.28$
f = frequency in Hertz
C = capacitance in farads
and X_C = capacitive reactance in ohms

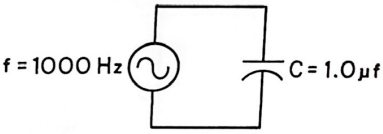
A simplification of the above formula that is easier to work with:

$$X_C = \frac{0.159}{f \times C}$$

Since the factor 2π is a constant . . . is always the same value . . . we divided 2π into 1 to get the 0.159 number. Now all that is left to do is multiply the frequency times the capacitance . . . then divide that answer into the fixed number on top (0.159) to get the answer.

Try the checkpoint to see if you can use the formula correctly. Watch out for the proper decimal place!

CHECKPOINT:



1. What is the capacitive reactance of the capacitor shown in the circuit above? X_C = _____ ohms.
2. If the frequency of the applied voltage were doubled, the X_C would be _____ ohms.
3. If the frequency were the same as in question 1, but C were half the value, the new X_C would be _____ ohms.

ANSWERS:
1. **159 ohms**
2. **79.5 ohms.**
3. **318 ohms.**

Did you notice that as frequency doubled, capacitive reactance halved? Also, with all other factors unchanged . . . when capacitance was halved . . . the reactance doubled? See how this relates to the inverse relationship of X_C to both frequency and capacitance? If not, practice using the formula some more . . . and reread the logic used to get it.

INFORMATION

Now then . . . let's relate the Xc and total capacitance concepts into one package.

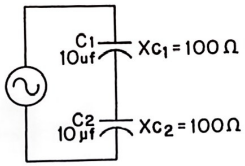
Remember that capacitors in series added like resistors in parallel, and, capacitances in parallel added like resistors in series. This means when we put capacitors in series the total capacitance decreases . . . when we put capacitors in parallel, the total capacitance increases. Since the reactance (or opposition to current) that a capacitor shows is inverse to its capacitance value . . . it follows that when we series capacitors, we will increase the total reactance, since C_T decreases. THIS SIMPLY MEANS REACTANCES IN SERIES ADD LIKE RESISTANCES IN SERIES. This is true for any type reactance . . . either capacitive, or inductive. It is also true that REACTANCES IN PARALLEL ADD LIKE RESISTANCES IN PARALLEL. (In other words . . . the total reactance of parallel capacitive reactances will be less than the least branch reactance).

Try the checkpoint!

If you didn't get the answers, here's a hint, so you can try again until you understand. You should have used a form of the "product over the sum" formula to find the total capacitance in question 1. ($C_T = C_1 \times C_2/C_1 + C_2$) . . . and total reactance in problem 4. You should have simply added the series reactances in question 2 . . . and added the capacitance values to find C_T for question 3. If you missed these . . . recycle yourself through the reading material which is pertinent.

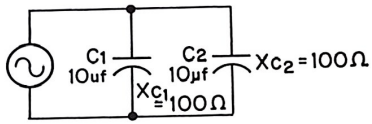
Now we've talked about factors that influence capacitance . . . factors that influence capacitive reactance . . . and we have seen how total capacitance and total Xc can be solved for series and parallel circuits.

REFERENCE & DATA



TOTAL c = 5 µf
TOTAL Xc = 200 Ω

SERIES C CIRCUIT

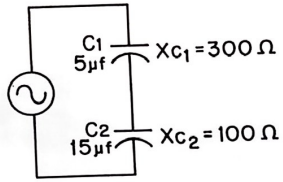


TOTAL c = 20 µf
TOTAL Xc = 50 Ω

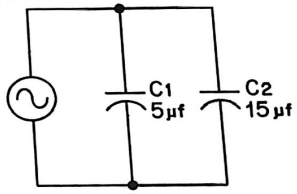
PARALLEL C CIRCUIT

CHECKPOINTS

CHECKPOINT:



1. What is the total capacitance of the circuit shown above? _____ uf.
2. What is Xc total? _____ ohms.
3. What is the total capacitance of the circuit shown below? _____ uf.



$Xc_1 = 300\,\Omega$
$Xc_2 = 100\,\Omega$

4. What is the total Xc of this circuit? _____ ohms.

ANSWERS:

1. **3.75 uf**
2. **400 ohms**
3. **20 uf**
4. **75 ohms**

THE RC CIRCUIT

Let's move on now to a quick analysis of how current and/or voltage distributes itself in circuits that have both resistance and capacitance. We'll confine ourselves to AC voltage and current . . . since you already understand that in DC, once the capacitor is charged to E_A, current ceases (since the capacitor "blocks DC").

Let's look at the simple RC series circuit first.

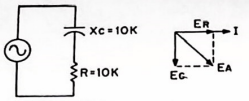
Remember that in the series RL circuit (resistor and inductor) . . . the component which had the greatest opposition in ohms to the AC current was the controlling factor. THE SAME IS TRUE FOR THE SERIES RC CIRCUIT. If the R and the Xc are equal, the circuit current will be 45 degrees out of phase with E applied . . . If Xc is greater than R, the circuit current will be more than 45 degrees "out of phase" with EA (somewhere between 45 and 90 degrees . . . depending on how much greater Xc is than R) . . . If R is greater than Xc . . . then I will be less than 45 degrees out of phase with EA. Recall that we can logically conclude this because if the circuit were purely capacitive (no resistance present), the phase angle would be 90 degrees . . . if the circuit were purely resistive . . . the phase angle would be zero degrees . . . if both R and Xc are present . . . then the results will be somewhere between the two extremes of 0 degrees and 90 degrees.

Don't try to memorize the vector diagrams—simply use them to help you understand the interrelationships of the electrical quantities.

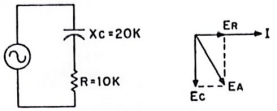
The key difference between analyzing the RC circuit and the RL circuit lies in the fact that for the **RC circuit . . . current leads voltage.** For the **RL circuit . . . voltage leads current.** (Our old friend "ELI the ICE man".)

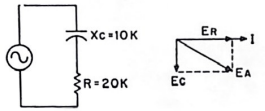
In essence . . . the capacitor opposes a change in VOLTAGE . . . an inductor opposes a change in CURRENT.

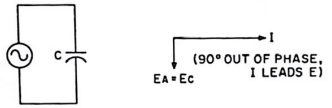
Keeping the above facts in mind . . . try the next checkpoint.

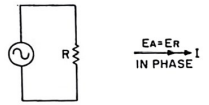


SERIES RC CIRCUIT
R = Xc PHASE ANGLE = 45°





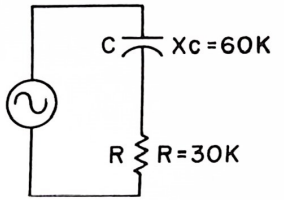




CHECKPOINT:

1. Will current for the circuit shown below lead or lag the applied voltage?

   _____ .



2. Will the circuit phase angle be greater or smaller than 45 degrees?

   _____ .

3. If R is doubled, would the circuit current be out of phase with the applied by zero degrees, 45 degrees or 90 degrees?

   _____ degrees.

4. If the value of the **capacitor** is doubled, would the phase angle increase, decrease or remain the same?

   _____ .

ANSWERS:

1. **Lead**
2. **Greater than 45 degrees**
3. **45 degrees**
4. **Decrease** (because Xc would halve)

For parallel RC circuits, the same basic premise (regarding circuit current) used in RL circuits is true. That is, regarding which component will have the greater effect on circuit current . . . and the phase angle between circuit current and E applied.

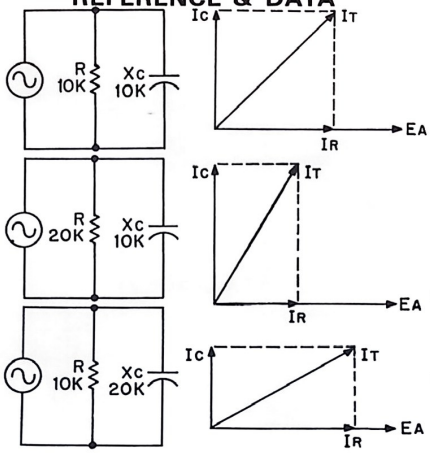
The premise is: The branch with the least opposition to current will have the greatest current through it . . . therefore will have the greatest effect on total current. WATCH OUT THOUGH . . . when dealing with RC circuits, it is a common error for student to get Capacitance and Capacitive Reactance confused. Remember that they are inverse to each other. Small C means higher Xc, and vice versa.

INFORMATION

We can conclude then that if R = Xc in a parallel RC circuit . . . the circuit phase angle will be 45 degrees. If R is greater than Xc . . . then more current will flow through the capacitive branch . . . and the circuit will act more capacitively . . . hence, phase angle will be between 45 and 90 degrees. If Xc is greater than R . . . then the opposite is true and the circuit phase angle will be less than 45 degrees . . . and be somewhere between 0 degrees (a pure resistive circuit) and 45 degrees (a circuit where R=Xc.)

To see if you understand these principles . . . try the next checkpoint.

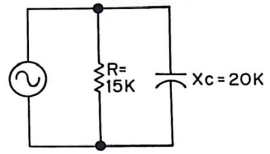
REFERENCE & DATA



CHECKPOINTS

CHECKPOINT:

1. Refer to the circuit below and determine if the circuit current leads or lags Ea.
   IT _____ Ea.



2. Will the phase angle be less than 45 degrees . . . more than 45 degrees . . . or exactly 45 degrees?
   _____.
3. If the value of **capacitance** were decreased . . . would the phase angle increase, decrease or remain the same?
   _____.
4. In order to achieve a phase angle of 45 degrees for this circuit, would the applied FREQUENCY have to be increased, decreased or kept the same?
   _____.

Trust you got those answers correct. If not . . . here's the thinking you should have used.

***For question 1** . . . we can make a general statement which is true in virtually all cases . . . If there is any "net" capacitive reactance in the circuit . . . the resultant circuit total current will lead E applied by some amount. THIS IS TRUE FOR BOTH SERIES AND PARALLEL RC CIRCUITS. (By the way . . . if there is a net "inductive reactance" in the circuit . . . the voltage will lead the current by some amount). It may help you to remember the concept that inductors oppose changes in current . . . thus voltage leads . . . capacitors oppose a change in voltage . . . thus current leads.*

For question 2 . . . since Xc was greater than R . . . then there will be more current through the R branch (since E is the same across both components in a parallel circuit) . . . hence, the resistive branch has more effect on total current . . . therefore, the total current will lead Ea by less than 45 degrees.

The thinking on question 3 is: if **capacitance** were decreased . . . then Xc would increase (remember the inverse relationship?). If Xc increased . . . then the current through the capacitor branch would decrease . . . and the resistive branch current is even more in control of IT . . . hence the phase angle would decrease.

ANSWERS:

1. **Leads**
2. **Less than 45 degrees**
3. **Decrease**
4. **Increased**

***For No. 4** . . . in order to achieve a phase angle of 45 degrees . . . R and Xc would have to be equal. Changing frequency doesn't change R . . . but does change Xc. Since Xc is now greater than R, we need to decrease Xc to get it equal with R. In order to do this, we must increase the frequency (again, remember the inverse relationship between f and Xc).*

Once more, let's say that you shouldn't worry about all the vector diagram details . . . but should try to understand:

1. The concept of Xc being inversely proportional to f and C.
2. The concept that in series circuits containing resistance and reactance . . . the larger value controls . . .
3. In parallel resistive and reactive circuits . . . the smaller ohmic value branch controls (to a larger degree) the circuit current . . . hence, the phase angle, etc.

We've "laid it on you" pretty heavily in theory here regarding inductance, capacitance and reactances . . . but it will be helpful to you as an electronics enthusiast to at least get the general concepts of what we've been talking about. You must know the X_L and X_C formulas for your FCC test. The vector analysis is not necessary . . . but was mentioned to illustrate graphically the general concepts. We have put all this basic info in a simple chart form. If you understand the statements on the chart . . . you've got the key information.

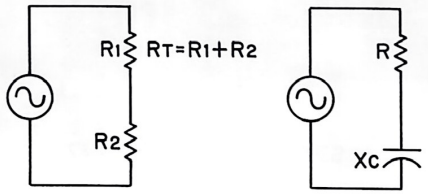
CHANGING PARAMETER	RESULT
Frequency Increases (↑)	X_L will ↑ X_C will ↓
Frequency Decreases (↓)	X_L will ↓ X_C will ↑
Inductance Increases (↑)	X_L will ↑
Inductance Decreases (↓)	X_L will ↓
Capacitance Increases (↑)	X_C will ↓
Capacitance Decreases (↓)	X_C will ↑

INDUCTORS	CAPACITORS
L_{TOTAL} for Series $L's = L_1 + L_2 \ldots$ etc.	C_{TOTAL} for Series $C's = \frac{C_1 \times C_2}{C_1 + C_2}$
L_{TOTAL} for Parallel $L's = \frac{L_1 \times L_2}{L_1 + L_2}$	C_{TOTAL} for Parallel $C's = C_1 + C_2 \ldots$
$X_L = 2\pi fL$	$X_C = \frac{0.159}{fC}$

THE CONCEPT OF IMPEDANCE

We have talked about current and voltage relationships in AC circuits containing resistance, capacitance and/or inductance. We have talked about the ohms of opposition to current flow for resistors (called resistance) and for capacitors or inductors (called reactance). Right here, let's introduce you to a concept in AC circuits which is as fundamental as E, I, and R are to Ohm's Law.

Any electronic circuit containing any, or all of the components we've been talking about, will exhibit opposition to current flow. THIS TOTAL NET OPPOSITION TO CURRENT FLOW IS CALLED THE CIRCUIT **IMPEDANCE.**



Z_T DOES NOT EQUAL THE SIMPLE ADDITION OF R + Xc, BUT RATHER

$$\frac{E_T}{I_T}$$

INFORMATION

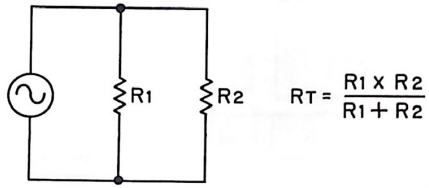
Impedance then, is the total opposition the source "sees" to current flow. Another way of stating this is to say that the ratio of E_T to I_T is the impedance . . . or opposition to current. Ohm's Law states that ohms of opposition equals E/I. Because the presence of any reactive component (L or C) in an AC circuit causes circuit current/s to be out of phase with circuit voltage/s . . . it is logical to expect that we cannot just simply add up the reactances and resistances to find total circuit opposition (impedance).

For our purposes . . . it is only necessary that you realize that the circuit impedance (commonly represented by the symbol Z) equals the circuit voltage divided by the circuit total current. The only difference between Z and R is that Z is made up of a combination of R and X (reactance). For PURELY resistive AC circuits . . . you can deal with R-total as always. For PURELY REACTIVE circuits (*All C's or All L's*) you can deal with the reactances just like you do resistances to find total opposition. When **both resistive and reactive** components are present in the same circuit . . . it takes vector type analysis, or other math to analyze . . . but *in ALL cases . . . the total opposition equals E applied divided by I total.*

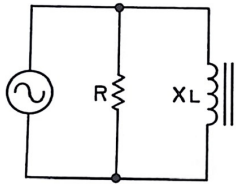
Try the checkpoint!

REFERENCE & DATA

$Z_T = \frac{E_T}{I_T}$ IN ALL CASES



$R_T = \frac{R1 \times R2}{R1 + R2}$



Z_T DOES NOT EQUAL

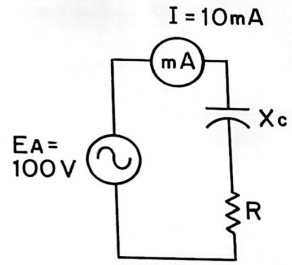
$\frac{R \times Xc}{R + Xc}$ BUT RATHER $\frac{E_T}{I_T}$

CHECKPOINTS

CHECKPOINT:

1. What is the Z (impedance) of the circuit shown below?

_____ ohms.



2. Would the circuit impedance increase, decrease, or remain the same if frequency were increased?

_____.

ANSWERS:

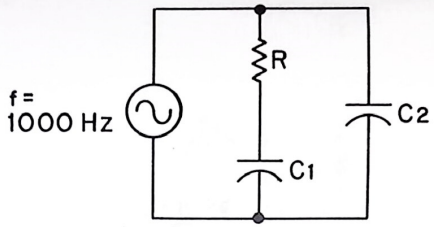
1. **10K ohms.**
2. **Decrease**

How'd we get those answers? Well, Z = E/I . . . thus, 100v/10 mA = 10K ohms. If frequency is increased . . . then Xc will decrease (look at the formula). If Xc decreases and R stays the same . . . then it is logical that the total opposition must go down. This brings about a very "nifty" general statement regarding circuit total resistance and/or total impedance.

NO MATTER WHAT KIND OF CIRCUIT . . . SERIES, PARALLEL OR SERIES-PARALLEL . . . IF ANY ONE OR MORE OF THE ELEMENTS CHANGES VALUE OF OPPOSITION . . . THE TOTAL CIRCUIT OPPOSITION WILL BE CHANGED.

If all the other elements remain constant in value . . . but the opposition of one element is increased . . . the total circuit impedance will increase. Conversely, if an element's value of opposition decreases . . . while all other elements remain the same . . . the circuit total opposition (Z for AC circuits) will decrease. Thus, changing the value of a component (R, C or L) . . . or changing the frequency applied (where reactive components are involved) will change the circuit impedance. Don't be fooled into thinking that the total opposition will change by the same value as the element changed . . . unless, of course, it's a purely resistive circuit. Summarizing what we've been saying . . . if any element's ohmic value of opposition changes, the circuit's total opposition will change, THE SAME DIRECTION.

Apply this knowledge to the checkpoint!



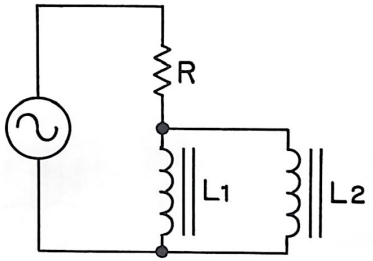
CHECKPOINT:

1. If the frequency of applied voltage is decreased . . . would the circuit Z increase, decrease or remain the same? _____ .
2. If R is increased in value, would the Z increase, decrease or remain the same? _____ .
3. If C_2 is doubled in value, would the circuit Z increase, decrease or remain the same? _____ .

ANSWERS:

1. **Increase**
2. **Increase**
3. **Decrease**

Now try this one!



CHECKPOINT:

1. If the frequency of applied voltage for the circuit shown at the left is decreased . . . would the circuit Z increase, decrease or remain the same? _____ .
2. If R is increased in value, would the Z increase, decrease or remain the same? _____ .
3. If L_2 is doubled in value, would the circuit Z increase, decrease or remain the same? _____ .

ANSWERS:

1. **Decrease**
2. **Increase**
3. **Increase**

THE RESONANT CIRCUIT

Since we have now studied inductance, inductive reactance and RL circuits . . . capacitance, capacitive reactance and RC circuits . . . let's put all these components together and study a very interesting phenomonon called **Resonance.**

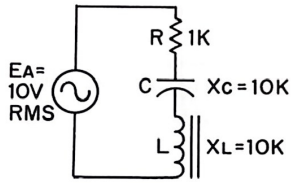
We'll start with a series RLC circuit and the phenomenon of **series resonance.**

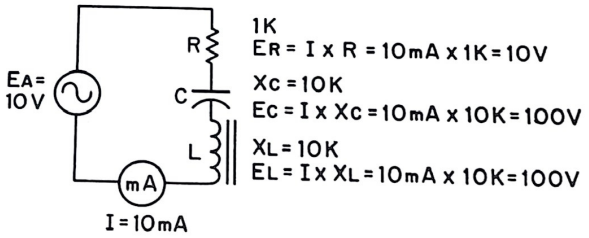
Look at the circuit in column 2 and note the values of reactances and the resistance value.

Because X_L (inductive reactance) and X_C (capacitive reactance) affect circuit current and voltages in "opposite ways" . . . some interesting things happen in this circuit. In effect . . . the X_L and the X_C cancel each other out . . . so the source sees a circuit where the only effective limitation on current is the R value within the circuit. (This is assuming a perfect coil with no resistance and a perfect capacitor, with no resistance . . . in which case they would perfectly cancel.) Assume the theoretically "perfect" condition . . . what would be the current in this circuit?

Well, using common sense and Ohm's Law . . . if the reactances cancel each other, the circuit impedance is equal to the R value of 1K ohm. Current = voltage divided by resistance (or impedance) . . . thus 10v/1K = 10 mA of circuit current.

That was easy wasn't it? Now, here is where the fun begins. Since the current is the same through all parts of a series circuit . . . then the 10 mA of current must be passing through the X_C and the X_L as well as the R. Using Ohm's Law to solve for voltage drops we find that 10 mA times X_L of 10K = 100 volts . . . AND, 10 mA times X_C of 10K = 100 volts. Wow! With only 10 volts of E applied, we're getting 100 volts across the coil, and 100 volts the capacitor . . . THAT'S RIGHT! The secret is that these reactive voltages are equal. . . BUT OPPOSITE IN PHASE . . . thus, as far as the total circuit is concerned E_A is dropped across the R, and the reactive voltages cancel each other. Nevertheless, there REALLY IS 100 volts across each reactance, individually. If we were able to have a meter (voltmeter) which did not "load" down the circuit . . . we could actually measure that voltage. This unusual circumstance occurs in series resonant circuits. In fact, one way of judging the "Quality" of the reactive components is to note how many times greater their voltage drops are than E applied. This is called the **Q** of the circuit. It's obvious then that this ratio is directly related to how many times greater the X_L or X_C is, than the R.

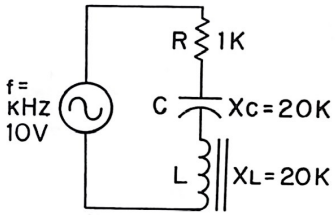




In other words . . . Q for a series resonant circuit = X_L/R. Because the I is the same through the R and the reactances . . . then the reactive voltage drops are this same ratio to E applied. This means that Q for a series resonant circuit also equals E_C/E_A or E_L/E_A. In our example the reactive component voltages were 100 volts . . . E applied was 10 volts . . . thus Q = 100/10 = **10.** Using the X_L/R formula gives us the same answer . . . 10K/1K = **10.** This "magnification" of voltage is only possible because the circuit current is limited only by R . . . THAT IS . . . CURRENT IS MAXIMUM AT SERIES RESONANCE . . . and is of a much greater value than if the reactances were limiting and determining the current.

What would happen if we changed the value of either C, L or the frequency of the applied voltage . . . That's right, the reactances would change, and would no longer be perfectly equal and thus "cancel" each other's effect. The circuit would then NOT BE RESONANT. Now what would change? X_L would no longer equal X_C . . . thus whichever was greater would more than cancel the other . . . and we would then have the equivalent of either an RC circuit, or an RL circuit. The NET REACTANCE in the circuit would be the difference between the two reactances . . . that, in series with the R, would then determine the impedance.

O.K. Let's see if you have the main points regarding series resonant circuits. Perform the checkpoint.



CHECKPOINT:

Referring to the circuit in column 2:

1. Determine I _____ mA.
2. Determine E_L _____ volts.
3. Determine E_R _____ volts.
4. Determine "Q" _____ .
5. What would X_L be if frequency is doubled? _____ ohms.
6. What would be the "net circuit reactance" if the frequency is doubled? _____ .
7. Would the circuit impedance (Z) be higher, lower or the same as it was at resonance? _____ .
8. Would the circuit current be higher, lower or the same as it was at resonance? _____ .

ANSWERS:

1. **10 mA.**
2. **200 volts**
3. **10 volts**
4. **20**
5. **40K ohms**
6. **30K ohms** (Because X_L doubled from 20K to 40K when frequency doubled . . . and X_C went to 1/2 its original value of 20K when frequency was doubled, or 10K . . . so in effect there is a difference of 30K between the X_L and the X_C . . . or there is a net inductive reactance of 30K ohms.)
7. **Higher**
8. **Lower** (higher Z means lower I with a given applied voltage)

Let's take a quick run through the answers and how they were derived . . . then we'll give you a summary of the characteristics of a series resonant circuit for quick-study purposes.

INFORMATION

For question 1 . . . I = E/Z. In this case Z=R because the reactances cancel each other, since they are equal in value and opposite in type. I = 10v/1K = 10 mA.

2.—E_L = I x X_L = 10 mA x 20K = 200v

3.—E_R = I x R = 10 mA x 1K = 10v.

4.—Q = X_L/R (or E_L/E_A) = 20

5.—X_L is directly related to frequency and/or inductance. In this case L stayed the same and frequency was doubled . . . then X_L would double. (Remember X_L = 2 f_L formula?) Since the 2 pi and the L were constant, but f doubled . . . the product, or answer is twice as great.

6.—Explanation given in **answers** column.

7.—Since the circuit impedance would now be made up of 1K of R and 30K of "left-over" X_L . . . rather than just the R, as at resonance . . . obviously the circuit Z would increase.

8.—Since circuit current is inverse to circuit impedance, and impedance increased . . . then I must decrease.

In column 2 we have put a little "Summary Chart" for series resonance. Try to learn these key facts!

Moving on . . . let's talk for a few minutes about **Parallel Resonance.**

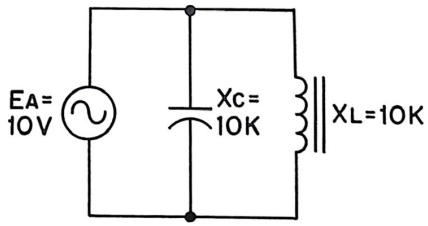
Again . . . resonance (for our purposes) occurs when X_L = X_C. We will only consider the theoretical "perfect" coil and capacitor (no internal resistance). In a practical sense, all these components are not perfect . . . but the characteristics we mention are true in a general sense for parallel resonant circuits . . . and you need to know these "generalizations" for your FCC test.

Look at the circuit in column 2. If X_L really does equal X_C . . . then both "branches" should have equal currents . . . because in parallel circuits E is the same across all branches. Each branch current = E/opposition in ohms. In our example I = 10 volts/10K = 1 mA for each branch.

REFERENCE & DATA

CIRCUIT CHARACTERISTICS AT SERIES RESONANCE

1. X_L = X_C (net reactance = 0)
2. Z = R (thus Z is minimum)
3. I = maximum
4. Circuit Phase Angle = 0°
5. E_L or E_C = Q times E applied
6. $Q = \frac{X_L}{R}$ or $\frac{X_C}{R}$ or $\frac{E_L}{E_A}$ or $\frac{E_C}{E_A}$



CHECKPOINTS

Recall that for a capacitor, current leads voltage by 90 degrees; for a coil, current lags voltage by 90 degrees. This means that the current through the capacitor branch is 180 degrees out of phase with I_L *(or in the opposite direction) Since these currents are equal and opposite . . . they "cancel". The net circuit current (if components had no resistance but were purely reactive) would be zero. By logic then, this theoretical circuit condition would yield a circuit impedance of infinite resistance. E/0 = infintiy. In "real life", the components are not perfect . . . hence there would not be perfect cancellation of current . . . but the current would be* **minimum** *at resonance. We've summarized circuit conditions for parallel resonance. Learn these key facts for the test.*

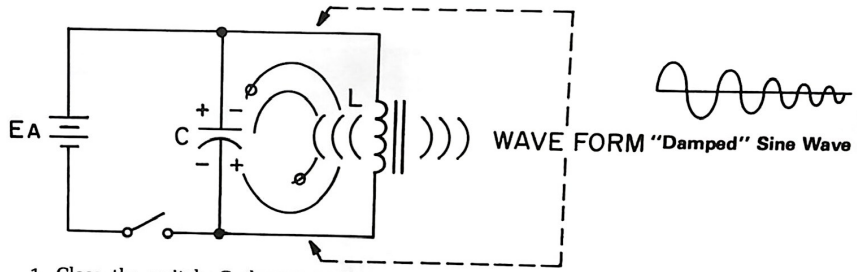
CIRCUIT CHARACTERISTICS FOR PARALLEL RESONANCE

1 $X_L = X_C$
2 Z = maximum
3 I = minimum
4 Phase angle = 0°
5 $I_L = I_C = Q \times I_{circuit}$
6 $Q = \frac{I_L}{I_{line}}$ or $\frac{I_C}{I_{line}}$

* I_{line} = current from source (outside of **LC tank circuit)**

We mentioned a new term for you in the Summary chart. The term **tank circuit** is frequently used in reference to parallel LC circuits. It is derived from the fact that these reactive components "store" electrical energy . . . much as a tank stores liquid, or whatever.

Incidentally, we mentioned the term **resonance** without explaining to you exactly what that term means. For the parallel "tank" circuit, it is the natural frequency at which the capacitor would discharge its electrons through the coil . . . which would build up the magnetic field about the coil . . . then when the capacitor was fully discharged, the coil's field collapses . . . inducing voltage of opposite polarity across the coil . . . which will charge the capacitor to that E . . . and then the process repeats. After the coil's field has collapsed . . . the capacitor will again discharge . . . but this time in the opposite direction . . . etc. etc. Interestingly enough . . . the voltage that appears across this "tank" circuit is our familiar AC sine wave. When we permanently attach an AC source to the tank . . . of course, the only energy the source needs to provide is enough to make up for the "losses" (heat losses due to I^2R loss of components) in the circuit. The frequency at which this natural exchange of energy from the capacitor's electric field . . . to the coil's electromagnetic field . . . back to the capacitor's electric field, etc. occurs is called the resonant frequency. And, as stated earlier . . . this frequency is also where $X_L = X_C$. There is a formula for finding this frequency. It is:



1. Close the switch. C charges to EA value.
2. Open switch. C discharges through L.
3. When C is fully discharged, coil field collapses, inducing EMF and charging C to opposite polarity.
4. C discharges through L in opposite direction from original.
5. Above sequence repeats over and over until losses in circuit "use up" the energy.

If there were no circuit losses, the waveform would look like this

$f_r = 0.159/\sqrt{LC}$ or $(1/2\pi\sqrt{LC})$

INFORMATION

Another way of looking at the resonant frequency is to imagine that you are pushing a swing with someone in it. If you push "at just the right moment", the person will continue to swing at the same level. If you push at the wrong moment . . . you will change the level of the swing . . . or may even stop it. The "frequency" at which you push, is the natural, or resonant frequency of the swing. In the electrical circuit . . . the resonant frequency is the frequency at which new energy "injected" into the circuit will sustain the level of voltage and current and overcome the losses. It's not too important that you know any deep theoretical knowledge here . . . but if you have the concept that there is one natural frequency . . . the resonant frequency . . . for any given LC combination.

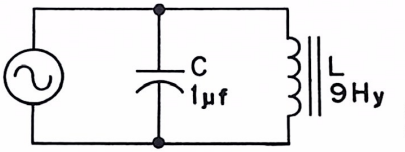
Try using the "resonant frequency formula" on the problem. HINT:

$f_r = 0.159/\sqrt{LC}$

Where f_r= the resonant frequency in Hertz.
L = inductance in Henrys
C = capacitance in farads.

Watch out for your decimal places. Good luck with the checkpoint!

REFERENCE & DATA



CHECKPOINTS

CHECKPOINT:

Solve for the resonant frequency of the circuit shown in column 2.

f_r = _____ Hertz.

ANSWER:

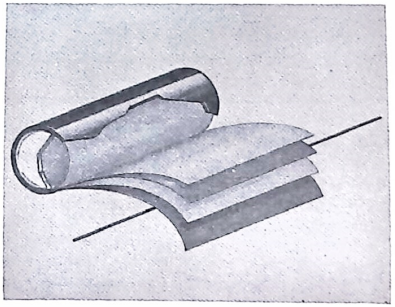
f_r = 53 Hertz.

By the way, you can find the resonant frequency of a series LC, or RLC circuit using the same formula.

THE ELECTROLYTIC CAPACITOR

Time now to move ahead from the DC and AC circuit theory portion of study to look at several components you will need to have a basic knowledge of for the FCC test. These components include some information about **Electrolytic capacitors, semiconductor diodes** (including Zener diodes), basic **vacuum tube** information and **transistors.**

You have already learned that a capacitor is composed of conductive plates separated by a non-conductor material, called the "dielectric". There is one particular type of capacitor that is unique; you need to know some of its characteristics. This is the **Electrolytic capacitor.**



"Photo Courtesy of Centralab, the Electronics Division of Globe-Union, Inc."

One of its key characteristics is that it provides a "lot" of capacitance for its size. The main reason for this is that the dielectric thickness is VERY SMALL. This type capacitor uses aluminum-foil for its plates . . . and has a "semiliquid" material between the plates that forms the actual dielectric through electrochemical action when a DC voltage is initially applied to the capacitor. In fact, this initial process is called "forming". A very important characteristic to remember regarding the electrolytic capacitor is that it is POLARITY CONSCIOUS. That means that it can only be connected in a DC circuit ONE WAY. They are marked so that you know which lead of the capacitor is the positive side, and which is the negative. If you put one into the circuit backwards . . . or try to put it into an AC circuit where the polarity of applied voltage changes . . . "POW"! It may blow up . . . or at least swell up and let out a strong smokey odor . . . while it is in the process of being DESTROYED.

The reason this type capacitor is polarity conscious is due to the "chemistry" involved in the semiliquid dielectric. When current is passed through the capacitor the wrong way . . . it shorts out . . . heats up and destroys itself. **Electrolytics,** as they are often called, find application wherever there is need of high values of capacitance in DC CIRCUITS. Examples of usage include: power supply filters, "bypass" capacitors, etc. Mainly in power supply circuits, for vacuum tube circuitry.

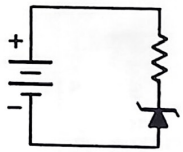
THE ZENER DIODE

One type semiconductor diode we have not discussed yet is the **Zener** diode. This component finds usage because its main characteristic is that once it starts conducting current through itself "in the reverse" direction (compared to the normal diode) . . . it maintains a very "constant" voltage drop across itself . . . even though the current though it varies. For this reason, it is often used as a **voltage regulator** or a **voltage reference.**

The symbol for the Zener diode is shown at right.

ZENER DIODE

When this diode is **reverse biased** . . . i.e., when a negative potential is placed on the anode and a positive potential is placed on the cathode, we have the normal usage of this device. As the potential difference between anode and cathode is increased, there comes a point where there is **avalanche** or **breakdown**, and the diode conducts heavily in the reverse direction. Normal diodes are operated so electrons flow from cathode to anode . . . Zeners are MADE to operate the opposite way in order to get this "constant voltage" characteristic.



REVERSE BIASED ZENER

INFORMATION

Let's see if you have picked up the most important points regarding the Electrolytic capacitor and the Zener diode. Try the checkpoint!

REFERENCE & DATA

CHECKPOINTS

CHECKPOINT:

1. Two key characteristics of electrolytic capacitors are: they have (high, low) capacity for their size? _____ ; they (can, cannot) be connected into AC circuits? _____ .

2. True or False? Probably the most common usage of electrolytic capacitors is as power supply "filter elements". _____ .

3. The most important characteristic of the Zener diode is that in operation it has a relatively constant (voltage drop across it; current through it)? _____ .

4. This characteristic becomes evident for the Zener diode when the voltage applied to it reaches a level to cause "breakdown", "avalanche", or, its "zener" point. True or False? _____ .

ANSWERS:

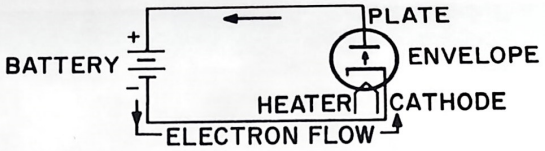
1. **High** capacity for size; and **Cannot** be connected into AC circuit.
2. **True**
3. **Voltage drop across it**
4. **True**

VACUUM TUBES

Moving on now . . . let's give you a quick refresher regarding **vacuum tubes.** You remember that in the Novice chapter we talked about the diode and triode tubes. Here, we'll briefly review and then we'll add basic knowledge regarding the **tetrode** and **pentode** tubes.

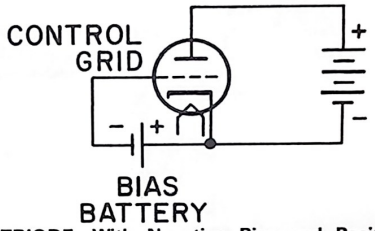
At this point, it may be good to "flat out" state a law of electricity that we have implied over and over again in our discussions . . . but have never really said in so many words. The "law of electric charges" is that **LIKE CHARGES REPEL . . . UNLIKE CHARGES ATTRACT.**

Electrons, being negatively charged particles, are attracted by electrically positive points, or areas, in an electrical circuit. This explains why in the diode, the electrons emitted by the heated cathode are attracted to the anode, or plate, of the tube if it is made more positive than the cathode. And, of course, when the plate is negative with respect to the cathode . . . the electrons do not go to the plate . . . hence no "plate current" flows. Recall that because of this "one-way valve" action . . . the diode could be used to "rectify". Next, we added a third element . . . called the control grid. By making this grid more (or less) negative with respect to the cathode . . . we could control how many electrons would travel from the cathode . . . through the grid area . . . and then on toward the plate. If the grid were made negative enough . . . no plate current would flow . . . even though the plate were positive. This DC potential difference between the grid (control grid) and the cathode is called **bias.** *The higher the bias . . . the more negative the grid is with respect to the cathode. As you'll see later . . . the amount of bias on the tube will determine the tube's "operating point". This really boils down to "how close to cutoff bias" (condition that shuts off plate current) the tube is operated.*



DIODE—In Conducting Condition

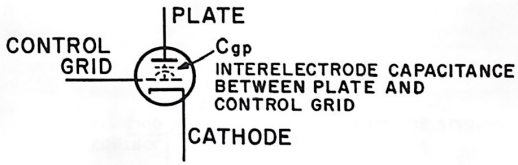
This third element in the tube, the control grid, opened up a whole "new ballpark" in electronics. The reason is that because the control grid is much closer to the cathode that the plate . . . the potential on the grid has much more control over the emitted electrons from the cathode than does the plate. In other words . . . a small change in potential on the grid can cause quite a large change in plate current. Because of this it is possible to place a small signal on the grid, and by proper circuit connections and choice of circuit components, produce a large signal at the plate of the tube. This is called **amplification.** We will look into this in more detail later; however, we wanted to review the purpose of the control grid before introducing two other elements which can make a tube even more useful.



TRIODE—With Negative Bias and Positive Plate Voltage Supplies

Recall that a tube with two elements is called a DIode. The prefix DI means two. A tube with three active elements is called a TRIode. The prefix TRI means three. Now let's look at the TETrode tube, and the PENTode tube. **Tet** meaning 4 and **Pent** meaning 5.

The triode invented by Lee DeForrest was probably the most significant advancement in electronics for a fifty year span. The main disadvantage of the triode tube was that if one tried to amplify too high a frequency, it did not work well. The reason is that the capacitance between the plate element and the control grid element couples signal from the plate circuit back to the grid circuit.



This is not desireable. As you know, Xc is inversely proportional to frequency. So, the Xc between plate and grid gets lower and lower as you try to amplify higher and higher frequencies.

INFORMATION

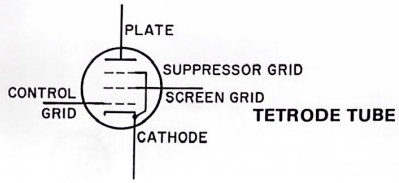
To reduce this plate-to-grid capacitance, so that higher frequencies could be amplified, someone got the idea of introducing a fourth key element into the tube, called a **screen grid.** The screen grid is located between the plate and the control grid. This in effect put two capacitors in series . . . thus reducing the total capacitance between plate and control grid. (Output circuit and input circuit.) note the schematic symbol for the TETRODE.

To make a long story short . . . this idea of the extra grid, the **screen grid,** worked! It was now possible to amplify higher frequencies. By the way . . . the screen grid is normally operated at a DC positive potential with respect to the cathode. Because the screen grid is positive, it was found that under certain conditions, the screen might "drag away" some of the plate current. This was generally undesirable, for the plate circuit is the output circuit. The electrons that were being drained from the plate circuit, were electrons which "bounced off" the plate due to high impact electrons coming from the cathode. These **secondary emission** electrons tended to be attracted to the positive screen. To reduce this undesired effect, a third grid was added to the tube, called the **suppressor grid.** It suppressed this undesired effect. Because the suppressor grid is electrically at the same potential as the cathode . . . negative with respect to the plate . . . electrons bounced off the plate are "repelled" back to it by the negative suppressor grid.

Note the "cutaway view" of a typical tube; it shows the internal construction of these elements we've been talking about (plus others).

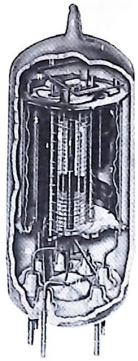
This really completes the BASIC family of vacuum tubes. The diode, triode, tetrode and pentode are really the key types of vacuum tubes. There are some special-purpose tubes which have been invented for particular jobs . . . but generally, all tubes are derived from the basic types just mentioned. The advantages of the tetrode and pentode over the triode are that they can amplify at higher frequencies . . . and there is good isolation between the input circuit (control grid) and output circuit (plate circuit). We look a little more deeply at how these tubes are used to amplify later in the book. Try the checkpoint to see if you picked up the needed terms and idea.

REFERENCE & DATA



TETRODE TUBE

PENTODE TUBE



Courtesy of RCA

CHECKPOINTS

CHECKPOINT:

1. A "tetrode" is a tube with four main elements. True or False? _____ .
2. Name the five elements in a pentode tube . . . not counting the heater.
3. The screen grid of a tube is normally operated at a (+, -) potential with respect to the cathode? _____ potential.
4. The suppressor grid in a pentode is physically located between the _____ grid and the _____ .
5. Which can amplify higher frequencies . . . a triode or a pentode? _____ .

ANSWERS:

1. **True**
2. **Cathode, Control Grid, Screen Grid, Suppressor Grid & Plate.**
3. **Positive**
4. **Screen grid and Plate**
5. **A Pentode**

Even as the vacuum tube was a huge step forward in the field of electronics . . . the transistor has become a component which probably is even more important in its impact and effect. It is not our intention to go into a lot of theory regarding this device . . . nor, is it needed for the purpose of the FCC exam. We do want to convey a few meaningful facts that we think you should know.

There is a "loose" comparison between the transistor and the triode tube. We don't want to stress this comparison, however, because the tube is a "voltage-operated" device . . . while the transistor is essentially a "current-operated" device. It is good to know that the **emitter** in the transistor is roughly similar to the **cathode** in the tube. The **base** of the transistor, in many cases, is used to control electrons from input to output circuit, just like the control **grid** is used for this purpose in a vacuum tube. The **collector** of the transistor, for many circuits, does an equivalent job to the **plate** in the vacuum tube circuit.

Transistors are generally used to perform the same type of electronic functions as vacuum tubes. These include, rectification, amplification and in various forms of oscillators.

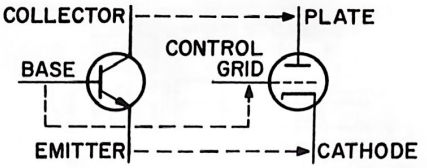
One term you need to know regarding transistors, because it is so often mentioned . . . is the term **Beta**.

Back in the Novice chapter, we defined it for you . . . but, let's repeat it here. **Beta** . . . sometimes called **forward current transfer ratio** . . . is the ratio of the collector current (output current) to the base current (input control current). In effect . . . this gives a general picture of the "gain", or amplification possible with the transistor. Thus, it is a fairly important transistor parameter. Learn the formula:

Rather than give you a checkpoint on these few facts we reviewed, we are going to suggest that you go back to the Novice chapter on this portion of material if you are not sure you understand the term Beta and need to learn the significance of PNP, NPN, etc.

Fasten your seat belts! From this point on we are going to accelerate you toward that goal of taking the General Class test and passing it.

We know that it is impossible for a person to learn all the theory and detail there is to learn in electronics . . . and hobbyists don't need to learn everything they will eventually learn in order to begin to enjoy their hobby. **Everybody learns by doing.** Because of the broad scope and variety of subjects you need to be exposed to for the FCC test . . . we are going to take a slightly different approach from here on . . . to help you begin to enjoy your hobby quicker.



NPN TRANSISTOR **TRIODE TUBE**

Loose Similarity between Transistor and Tube

Emitter—somewhat similar to **Cathode**
Base—somewhat similar to control **Grid**
Collector— somewhat similar to **Plate**

$$\text{Beta} = \frac{I_C}{I_B}$$

where I_C = collector current
I_b = base current.

INFORMATION

Up to this point, we have generally gone into quite a bit of detail on each subject covered . . . mainly because we felt the subjects were significant and foundational. If a person learns his "fundamentals" well . . . he can learn the rest far more easily. We felt that you, as a hobbyist or student, would find the understanding of Ohm's Law, basic circuits, and the fundamental components of which all electronics circuits are made up, to be well worth learning. After all, it's from these components (resistors, inductors, capacitors, tubes and transistors) that single function stages, such as amplifiers and oscillators, are made up . . . and from these stages, systems are built (containing combinations of these stages and components to perform a useful task).

Obviously, it is beyond the scope of this book to delve deeply into each and every one of the myriad topics associated with Amateur Radio.

Our approach from here on out will be to try to organize the many topics into general categories. We will not attempt too detailed a study of any given item, but will endeavor to give you the information you need to know to procure that coveted General Class License.

Good Luck! Stick with it . . . you're closing in on your goal!

APPLICATIONS OF COMPONENTS

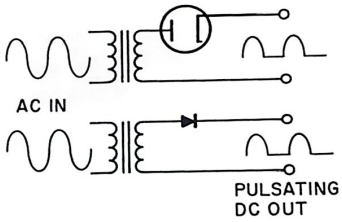
RECTIFIERS

Remember us mentioning the term **rectification** *(changing AC to pulsating DC) back in the Novice chapter? There are three basic* **rectifier** *circuits that you should be able to recognize, or draw, in schematic form, for the FCC test.*

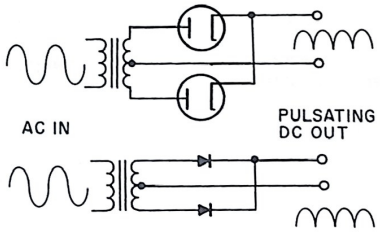
These are: the **Half-wave rectifier,** *the* **Full-wave rectifier** *and the* **Bridge rectifier.** *In the next column you will see a diagram of each of these types . . . both in vacuum-tube type, and semiconductor diode type. Learn to recognize these circuits . . . or, better yet, learn to draw them yourself without looking (use the 3rd Column).*

The reason the half-wave rectifier is called that is during only one half cycle (one alternation) is the plate positive with respect to the cathode (or anode positive with respect to cathode for the semiconductor). As you know, the only time these diodes will conduct is when the plate, or anode is positive with respect to the cathode . . . therefore, no current flows during the other alternation of the AC signal . . . and there is no output for that half cycle . . . hence, a half-wave rectifier.

REFERENCE & DATA



H.W. (Half-wave) RECTIFIERS



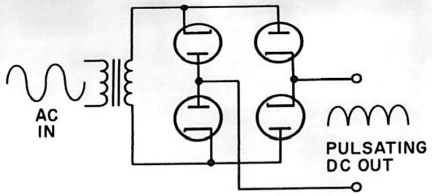
F.W. (Full-wave) RECTIFIERS

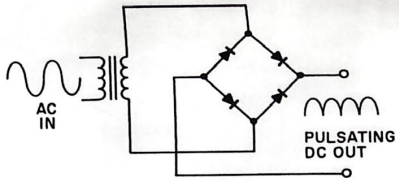
CHECKPOINTS

On the other hand . . . the F.W. (full-wave) rectifier uses two diodes, and they are connected in the circuit so that while one is ***not conducting . . . the other one is*** *. . . and we obtain output from the rectifier during* ***both*** *half-cycles of input . . . hence, full-wave rectification. You'll notice that the full-wave rectifier uses a "center-tap" on the transformer to achieve this condition. This means that only one half of the transformer secondary voltage is being rectified* ***at a time.***

Now, the half-wave rectifier had the drawback that it only provides output on one half cycle . . . the full-wave rectifier had the drawback that only half the secondary voltage could be used at a time . . . so to overcome these handicaps . . . someone came up with the **Bridge rectifier.** Here we use the whole secondary voltage . . . and we get output on both alternations . . . how about that?

It is not necessary that you memorize the input and output waveforms . . . but do learn to recognize the circuits by name.





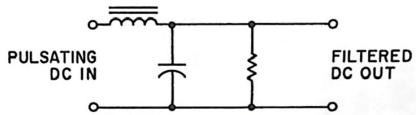
BRIDGE RECTIFIERS

POWER SUPPLY FILTERS

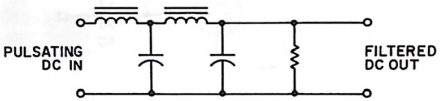
Because the output from the various rectifier systems is a "pulsating DC" rather than a "smooth" DC, it is common practice to **filter** the pulsating DC. We have illustrated the schematic diagrams for three commonly found power supply filters. Note our old friends the inductor and the capacitor. Study these until you can recognize them, and/or draw them and know their names.

The **choke-input filter** is recognized by the fact that the input side of the filter (side toward the unfiltered pulsating DC input) is a Choke. The number of sections is obvious from the schematic. The **capacitor-input** filter is named by the same reasoning. In the schematic it appears that the capacitor is closer to the filter "input" side. By the way . . . this circuit configuration is often called a "pi" type filter, because the two capacitors and the choke form the shape of the mathematical term π.

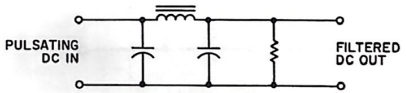
Sometimes two or more capacitors are connected in series, as at right. This is done in order to filter higher voltages than the voltage rating of one capacitor alone. The special resistor shown in parallel with each capacitor is called an **equalizing resistor.** Their job is to equalize the voltage drops across each capacitor so that none of the capacitors will take more than its share of the voltage. Learn the term **equalizing resistor.**



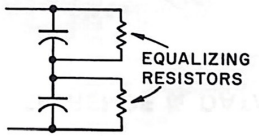
SINGLE-SECTION
"CHOKE-INPUT" FILTER



TWO-SECTION
"CHOKE-INPUT" FILTER



"CAPACITOR-INPUT" FILTER
(π Configuration)



INFORMATION

RF FILTERS

While on the subject of filters, we might as well mention a couple of names, or types, that may appear on the FCC test. These are not low frequency filters such as the power supply filters we just looked at. This, you can tell by the fact that the coils are not iron-core, such as those used at power frequencies, or audio frequencies, but rather are air-core inductors.

So you won't be caught off-guard, these filters are sometimes referred to as the **Constant-K** type.

The most important thing to remember about these filters is that the reactive elements layout identifies whether its pi- section, or T-section . . . and whether it's a high-pass, or a low-pass filter. As you can see . . . if the reactive elements form the shape of the term pi . . . it's called a pi-section filter . . . if they form the shape of a T . . . it's called a T-section filter. Now, for the "high-pass" and "low-pass" terms . . . let's quickly explain. High-pass means that it passes the high frequencies along . . . Low pass means that it passes the low frequencies along. With your knowledge that inductor's opposition increases with frequency, while capacitor's opposition to AC decreases as frequency increases, you can reason why the circuits are as shown. In the low-pass filters the inductors are "in series with the signal path", and offer low opposition to low frequencies . . . but high opposition to high frequencies . . . therefore, the low frequencies are passed along.

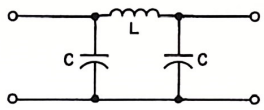
In the high-pass filters, the capacitor/s are in series with the signal path, and offer high opposition to low frequencies . . . but low opposition to high frequencies . . . therefore, high frequencies are passed along.

THE AMPLIFIER

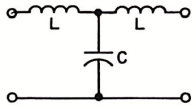
The next application of components we'd like to talk about is the "tying together" of resistors, capacitors and the vacuum tube to create an ***amplifier****. Really, what you're going to study here is just a "hot rod" application of Ohm's Law, which you've already learned. (Now, you can see why we worked you over so thoroughly back there . . . it makes this easier.)*

Look at the diagram of a typical triode amplifier stage. First let's analyze the DC voltages and currents. As you can see by looking at the **Equivalent DC circuit** diagram . . . R_2 and tube and R_3 form a simple series circuit. We've shown the tube as a variable resistance, since that is the way it acts. When the grid is made more negative . . . it's resistance increases. When the grid is made less negative (with respect the cathode), the tube **conducts** more . . . so it's resistance is effectively lower.

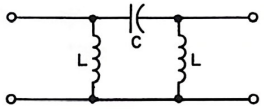
REFERENCE & DATA



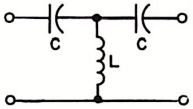
"PI-TYPE" LOW-PASS FILTER
(or Pi-section)



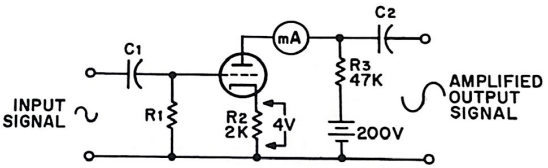
"T-TYPE" LOW-PASS FILTER
(or "T-section")



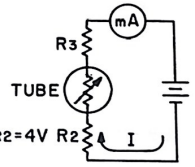
"PI-TYPE" HIGH-PASS FILTER
(or "Pi-section")



"T-TYPE" HIGH-PASS FILTER
(or "T-section")



TRIODE AMPLIFIER



DC EQUIVALENT CIRCUIT

Let's see if we can analyze the current and voltages for this simple series circuit. We know that E_{R_2} is 4 volts and that R_2 equals 2K ohms. To find the current through R_2, we use Ohm's Law . . . I = E_{R_2}/R_2. The answer is 2 mA. Since this is a series circuit we know that the 2 mA is common through the other two elements, the tube and R_3. We could calculate the voltage drop across R_3 by E_R = I x R_3 = 2 mA. x 47K = 94 volts. Since we know that the sum of the voltage drops of R_2, the tube and R_3 must equal E applied, we can figure the E drop across the tube. We know E_A is 200 volts . . . and we know the sum of E_{R_2} + E_{R_3} = 98 volts (4v + 94 v) . . . then the tube drop must be the difference, or 102 volts.

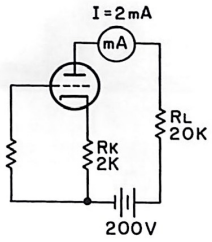
Now, we've said all that in order to say this. What would happen if we brought an AC signal into the grid through **coupling capacitor** C_1. Well, if the first alternation were **positive-going** this would decrease the **bias** (how negative the grid was with respect to the cathode) . . . and that in turn would cause the tube to conduct harder. In other words, it would decrease the resistance of the tube to DC current. Since R_2 and R_3 didn't change value . . . but the tube R decreased . . . then total resistance would be decreased . . . meaning more current would flow. If more current flows, the IxR drop across R_2 and R_3 will increase . . . leaving less of Ea to be dropped by the tube. In fact, this is what really happens. Interesting that while the input signal was going in a positive direction . . . the output across the tube is going in a less positive direction. For this type of amplifier there is a 180 degree phase shift from input to output . . . BUT DON'T WORRY ABOUT THAT FACT . . . it's not a "gotta know" thing for now.

The next alternation of an AC input signal would produce the opposite effect. Bias would increase . . . tube current would decrease . . . E_{R_2} and E_{R_3} would therefore decrease . . . and the tube drop would increase (the plate would become more positive with respect to the cathode). DON'T MEMORIZE ALL THESE DETAILS.

Let's sum it up by saying that a small change in grid voltage will cause enough change in plate current through the tube to make a fairly large change in output voltage. Since a small voltage change at the input has created a large voltage change in the output . . . we have VOLTAGE AMPLIFICATION. We threw in the above details . . . for no extra cost . . . for those who might be interested in how a tube amplifies a signal.

Let's give you a little checkpoint on applying Ohm's Law to a simple vacuum tube circuit. Before we do, here's a hint. The **bias** voltage (DC difference of potential between control grid and cathode) is developed by the I x R drop across the cathode resistor (R_K).

Now, try the checkpoint.



CHECKPOINT:

Refer to the diagram in column 2 and determine:

1. The value of bias voltage. Bias voltage (E_C) = _____ v.
2. The voltage drop across the tube from plate to cathode (called "plate voltage" and abbreviated as "E_b").
   E_b = _____ volts.
3. The voltage across R_L (the plate load resistor)
   E_{RL} = _____ volts.

ANSWERS:

1. **4 volts** (2 mA x 2K = 4v)
2. **156 volts** (200 v - E_{RK} & E_{RL})
3. **40 volts** (2 mA x 20K = 40 volts)

INFORMATION

Without going into great detail, we'd like to mention that the amount of bias (negative voltage on the grid with respect to the cathode) used for any given amplifier tube stage . . . determines its general operating characteristics. This is termed its **class of operation.** There are three main **classes of operation** for amplifiers and you should know these for our friend "Frank Charlie Charlie" (FCC). We've implied that these classes of operation only refer to vacuum tube operation . . . Let's clear that up . . . these classifications apply to BOTH TUBE AND TRANSISTOR AMPLIFIERS!

First, there is **class A** operation, in which plate (or collector) current flows all the time. (During 100% of the input signal cycle). This class operation produces the "highest fidelity" output . . . or, the most faithful reproduction in the output of the input signal. Because DC power is being used at all times, with, or without signal, Class A operation is the least efficient when comparing the DC power supplied to the circuit with the AC signal output power.

Class B is amplifier operation where the tube plate current (or transistor collector current) flows only during 1/2 the input cycle . . . because the tube or transistor are **biased** at **cutoff.** In other words, only the half cycle (or alternation) of the signal which "reduces bias" will cause conduction. For audio circuits, it takes a special arrangement of two tubes (or transistors) in a "push-pull" circuit to amplify without distortion. However, the class B amplifier has higher efficiency than the Class A type . . . because with no signal, there is very little conduction, thus little power required from the power supply. For RF circuitry, class B operation can be used where there is a tuned circuit to "fill in the other half cycle" . . . even with one tube or transistor.

Class C operation is the most efficient . . . but is only used in RF circuits where the "tank circuit flywheel effect" can complete the output waveform and prevent distortion of the input signal.

While on the subject of amplifiers, we'd better mention one "special" type that has an application in electronic circuitry. The **cathode follower** is a circuit often used for "impedance matching". The input impedance of this amplifier is high . . . the output impedance is low. So, when it is desired to transfer a signal from a high impedance circuit, such as the conventional amplifier stage, to a low impedance load (speaker, cable, etc.,) this circuit is useful. You won't be required to recognize or draw this stage . . . but should be familiar with the name **cathode follower**, and its principle characteristic of high input impedance, and low output impedance.

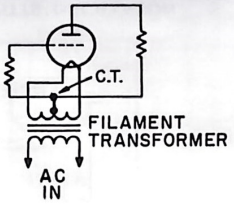
REFERENCE & DATA

CHECKPOINTS

Key things to remember here are:

1. Class A = conduction for 100% of input cycle
2. Class A = least efficient
3. Class B = conduction for 50% of input cycle
4. Class B = more efficient than class A
5. Class C = most efficient—conducts less than 50% of time
6. Class C = used in RF circuits with tuned circuits (to prevent distortion)

One last point that should be mentioned regarding amplifiers, because there might be a question on the FCC test regarding this. Most tubes in transmitters and receivers receive their filament voltage (heater supply) from the secondary of a power transformer, or filament transformer. In transmitters it is common practice to provide a **center-tap** *on the filament windings as a "return" connection point for the grid and plate circuits . . . when the tube does not have a separate cathode element . . . but uses the heater itself as the emitter of electrons for the tube. By "returning" the grid and plate circuits to the center tap, "hum modulation" of the signal is prevented. In other words . . . the 60 Hertz filament AC voltage is not superimposed on the desired signal being amplified. Also, this center-tap technique prolongs the life of the filament.*



CHECKPOINT:

1. Class A operation of an amplifier means that the tube or transistor current flows for _____ % of the input cycle.
2. Class B operation means that conduction takes place during _____ % of the input cycle.
3. Class C operation means that amplifier conduction takes place for less than _____ % of the input cycle.
4. The least distortion takes place in a Class _____ amplifier, but the highest efficiency is class _____ .
5. The cathode-follower amplifier has one key characteristic. In your own words, briefly describe this feature.
   _____
   _____
6. To prevent hum-modulation of a transmitter amplifier's signal, and to lengthen transmitter tube life, it is quite common to find a _____ filament winding used on the filament transformer.

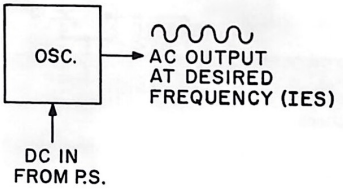
ANSWERS:

1. **100%**
2. **50%**
3. **50%**
4. **A; C**
5. **High input Z and low output Z**
6. **"center-tapped"**

THE OSCILLATOR

The subject we are about to discuss is very important to Radio Amateurs. Because oscillators are found in virtually all receivers and all transmitters . . . it is obvious that the FCC would ask some questions about this type circuitry.

We mentioned back in the Novice chapter that an oscillator converts the DC power supply voltages and currents into an AC signal of some sort. It is beyond the scope of this book to give you an "electron-chasing" analysis of oscillators, but . . . it is necessary that we expose you to the basic concept of how they work and help you recognize the diagrams of some of the commonly used types in amateur work.



BASIC OSCILLATOR

INFORMATION

If we distilled the theory down into the barest minimum . . . we could say that an oscillator is a "hot-rod" amplifier. All we mean here is that we take a little chunk of the output signal . . . and purposely feed it back to the input circuit . . . in proper phase (positive or **regenerative** feedback) to sustain oscillations.

To make an oscillator work there are four basic requirements:
1. DC power supply or source.
2. Amplification
3. Frequency determining system
4. Feedback in proper phase (to overcome circuit losses)

The important things to watch for in our discussions of several types of oscillators is "what determines frequency" and "how is feedback obtained". Watch for these as we point out the features of the common types of oscillators and you'll probably be able to recognize the various types.

Two very popular oscillator circuits are the **Hartley** oscillator and the **Colpitts** oscillator . . . so, we'll discuss them first.

Look at the vacuum-tube and transistor versions of the Hartley.

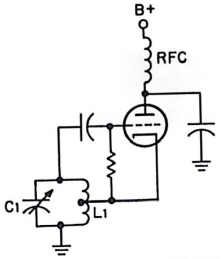
The key identifying feature of the Hartley is the **tapped coil** in the frequency-determining "tank" circuit. The DC voltage and current for this circuit are provided by the B+ supply. The frequency-determining device is the tank circuit composed of L_1 and C_1. Feedback is accomplished by the tapped coil in the tank circuit . . . and of course amplification is produced by the tube or transistor. We have the four ingredients for an oscillator . . . and it works!

The Colpitts oscillator is quite similar in circuit configuration . . . but instead of a tapped coil to control feedback . . . the Colpitts uses a **capacitive voltage divider** (2 capacitors in series). Look at the diagrams of the standard Colpitts oscillator and look for the capacitor voltage divider in the frequency-determining tank circuit and feedback path.

Again, we meet the four requirements for oscillation in the Colpitts circuit. DC comes from B+ or V_{CC} source. The LC "tank" circuit (L_1 and C_1 & C_2) determines frequency. Relative values of C_1 and C_2 determine the amount of feedback . . . and amplification is provided by the tube or transistor.

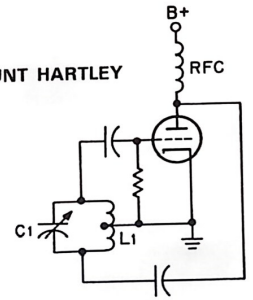
Two other types of oscillators that might appear on the FCC test are the **Pierce** crystal oscillator and the **Electron-coupled** oscillator (generally an adaptation of the Hartley or Colpitts . . . but using a pentode tube).

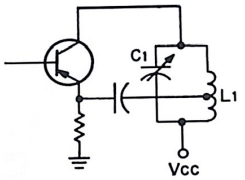
REFERENCE & DATA



SERIES HARTLEY

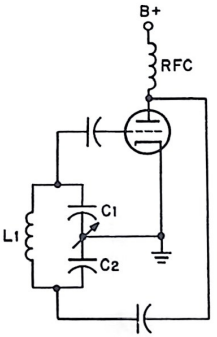
SHUNT HARTLEY



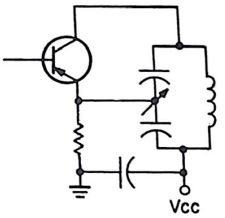


Emitter and Collector Circuit of Transistor Hartley Oscillator

NOTE: Tapped coil L_1 in each case.



COLPITTS OSCILLATOR



Colpitts Oscillator Emitter and Collector Circuit

NOTE: Capacitive voltage divider C_1-C_2 in tank circuit (coil NOTE tapped).

CHECKPOINTS

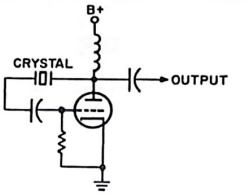
Look at the diagram of the **Pierce**.

Whenever you see a crystal shown in an oscillator diagram. . . it generally is the "prime" determiner of frequency for that oscillator. Again, B+ supplies the DC, the tube amplifies and feedback is accomplished by a combination of "interelectrode" tube capacitances and the external components. Thus, we have our 4 needed ingredients for oscillator operation. The key identifier of the Pierce circuit is that the crystal appears between the plate circuit and the input circuit (the grid, in this case).

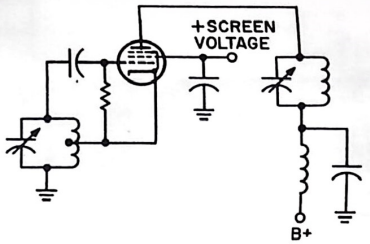
The **Electron-coupled** oscillator is identifiable by the fact that a pentode tube is used . . . and the screen grid of the tube is treated like the plate of the oscillator tube. In other words, the oscillator circuit proper does not depend on the plate circuit of the pentode . . . the screen serves as the oscillator plate. This means that the output circuit of the tube (the plate circuit) effectively isolates the load connected from the basic oscillator operation. This is good, and helps provide good frequency stability for the oscillator. Also, the plate circuit can be tuned to some multiple of the oscillator signal . . . and thus "frequency multiply" the oscillator signal. Notable identifiers of this circuit are the pentode tube . . . and the screen being treated like the plate of the oscillator.

May we recommend that for further details regarding oscillators, you should do more study (in ARRL books, etc.). We've given you the essentials here, but, if you'd like more information, there are a number of good books out on the topic of oscillators.

How about a little checkpoint here to see if you grasped some of these applications of components . . . and basic circuits we've been discussing.



PIERCE CRYSTAL OSCILLATOR
NOTE: Location of crystal helps identify this oscillator type.



ELECTRON-COUPLED OSCILLATOR
Hartley Oscillator Configuration

CHECKPOINT:

1. Draw a diagram (at the left) of a full-wave rectifier with pi-type capacitive input filter, and "bleeder" resistor (load resistor). Show the transformer feeding the rectifier-filter system as well. (Don't forget, for full-wave rectification, a center-tap is needed.)

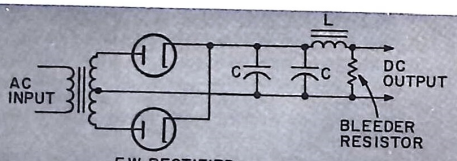
2. Draw a diagram of a "T" type constant-K filter that could be used as a "low-pass" filter.

3. The key identifying feature of the Hartley oscillator is its _____ _____.

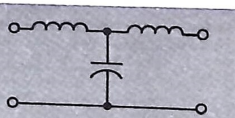
4. The key identifying feature of the Colpitts oscillator is the two _____ in series, which might be referred to as a _____ voltage divider.

5. The key identifying feature of the Pierce crystal oscillator is that the crystal appears between the _____ of the tube and the _____ of the tube.

6. The Electron-coupled oscillator uses a _____ type tube.



F.W. RECTIFIER



T TYPE CONSTANT K LOW PASS FILTER

ANSWERS:

1. **See left**
2. **See left**
3. **tapped coil** (or, tapped-inductor)
4. **capacitors; capacitive**
5. **plate and the grid (or input)**
6. **pentode**

INFORMATION

THE SYSTEM APPROACH

We've spent a great deal of time so far teaching you about single components, such as: resistors, capacitors, inductors, tubes and transistors. We have brought some of these components together to form basic **stages** or circuits, such as amplifiers, and oscillators. Now it's time we give you an overview of some systems that combine the components and stages into a total functional system. The two most important systems to radio communications, of course, are the **transmitter** and **receiver.**

As you already know, the transmitter has the job of producing a radio wave, which is in turn radiated into space by an antenna system . . . and then it's the job of the receiving antenna to pick up this transmission and feed it to a receiver . . . which processes the incoming signal and retrieves the "intelligence" contained in it (code, music, speech or teletype).

Every system . . . your phonograph, an automobile, a transmitter or a receiver, etc. . . . has three basic elements . . . at least. These elements are:

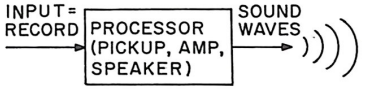
1. An input
2. A processor
3. An output.

In the case of the phonograph . . . the input might be the grooves in the record . . . the processor includes the pickup, the audio amplifier and the speaker system . . . the output is the sound waves, or disturbances of the air in front of the speaker/s.

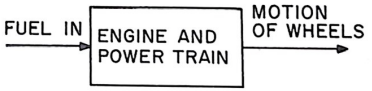
The automobile takes fuel as its input . . . processes it through its engine and power train . . . and creates the output of motion of the wheels. Are you beginning to get the idea of what is meant by a "system"?

REFERENCE & DATA

A SYSTEM



A PHONOGRAPH "SYSTEM"



AN AUTOMOBILE "SYSTEM"

CHECKPOINTS

CHECKPOINT:

Every system has at least 3 impertant parts. These are:

1. The _____
2. The _____
3. And the _____

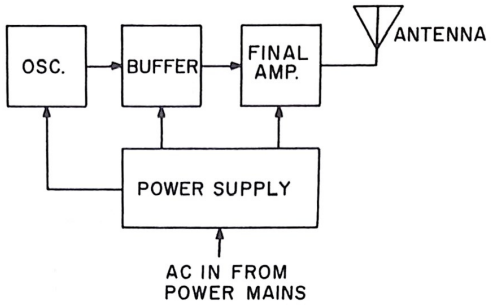
ANSWERS:

1. **Input**
2. **Processor**
3. **Output**

THE TRANSMITTER SYSTEM

Let's now take a quick overview of the **transmitter system**. The types we'll look at are: A CW (or code) transmitter, an A.M. type transmitter, an F.M. type transmitter and a special form of A.M. transmitter, known as a single-sideband (SSB) transmitter. We simply want you to get the systems approach of these. It's not expected that you will understand circuit theory at this point in your career. Let's hasten to say though . . . that all the systems we work with will be some combination of the basics you have been learning. Amplifiers . . . both audio frequency (AF) and radio frequency (RF) are much used. Oscillators are used in both transmitters and receivers. Power supplies (rectifiers and filters) are found in virtually all electronic equipment, unless battery operated. Various coupling, decoupling and tuning circuits using R, L and C elements are used through all electronic systems. So you see . . . you've got a good start!

Look at the block diagram of a simple 3-stage transmitter that could be "keyed" by a code key for CW transmissions.



C.W. TRANSMITTER

The function of each block in this **block diagram** is essentially as follows:

1. The power supply provides all the DC voltages and currents needed by the other stages in the transmitter.

2. The Oscillator provides the RF signal. It converts the DC voltages fed to it into an output signal at some selected radio frequency.

3. The **Buffer** stage is just an RF amplifier stage to build up the signal level and to isolate the **load** (in this case the final amplifier) from the oscillator.

4. The **Final P.A.** is the final power amplifier (P.A.) that further amplifies the RF signal to a level suitable to be transmitted by the antenna system.

We might add that a transmitter of this kind will generally be **keyed** (turned on and off to send code) in the **Final** stage . . . but it could be keyed in one of the preceeding stages if desired.

In summary then . . . this transmitter has an input of the AC power lines feeding the power supply. This electrical energy is processed by the power supply into DC . . . the oscillator processes this into a radio frequency signal . . . which is processed and amplified by the "buffer" and "final" stages and finally is fed as output to the antenna system. Simple isn't it?

In the case of the C.W. transmitter, the **intelligence** is in the form of dits and dahs . . . depending on how long the operator holds the sending key down and lets it up. With the key closed, the transmitter is producing RF output to the antenna . . . with it open (up) . . . no output.

INFORMATION

Now, to add audio intelligence directly, via microphone, tape deck or whatever . . . a couple more blocks are added to our basic transmitter block diagram.

Note in the diagram that we have added a **speech amplifier** and a **modulator** block. The speech amplifier obviously amplifies or builds up the level of the audio signal. The modulator stage builds the audio signal up further, to a level that can be fed to the **modulated RF stage**. The **modulated RF stage**, in addition to building up the RF signal level, as in the CW transmitter . . . also, combines the audio information with the RF to produce a **modulated RF** output signal . . . which is fed to the antenna system to be transmitted. The inputs to this system are: the power line AC plus the audio speech, music, or whatever. The transmitter processes this and generates an output of modulated RF wave or signal.

There are several systems of generating an F.M. (frequency modulated signal). The most direct method: the transmitter's oscillator is directly caused to change frequency by the audio signal. This method is called the "Direct" method of F.M. A simplified diagram is shown in column 2.

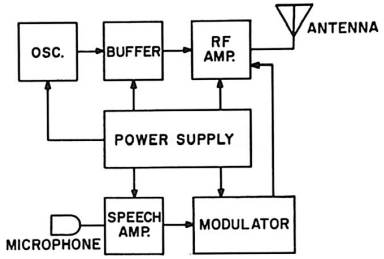
A quick "tour" through the transmitter yields the following:
The oscillator generates an RF signal. The frequency multiplier stage amplifies and multiplies the frequency of the oscillator signal. The final RF power amplifier (P.A.) builds up the signal to an appropriate level for transmission by the antenna. The modulator takes the audio signal as input and processes it so that the output of the modulator changes the frequency of the oscillator in accordance with the audio intelligence . . . thus directly an F.M. signal. The power supply does its usual job of providing appropriate DC voltages and currents for all the stages . . . having processed the AC input from the power mains.

Now, our special type of A.M. transmitter . . . the SSB (single-sideband) transmitter. Look at its functional diagram.

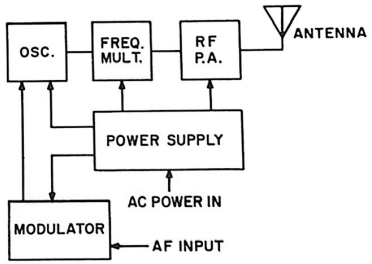
Incidentally, this is known as the **filter-type** sideband transmitter. There is another way of creating a single sideband signal . . . the **phasing** method . . . but we won't discuss it here, as the more popular method by far is the filter method.

"Walking our thoughts" through this transmitter, we see that there are several new blocks not shown in our other A.M. transmitter. DON'T GET WORRIED . . . YOU DON'T HAVE TO MEMORIZE THIS! Just get the concepts in mind . . . and you've done well.

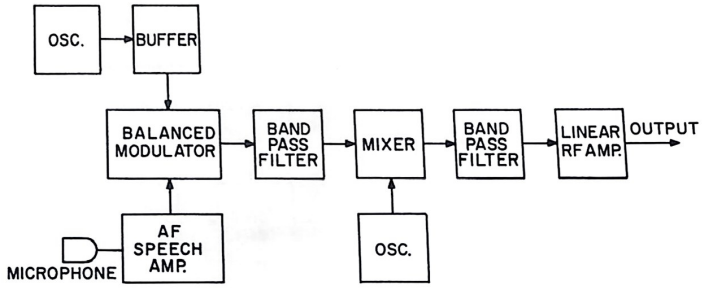
REFERENCE & DATA



A.M. (amplitude modulated) TRANSMITTER



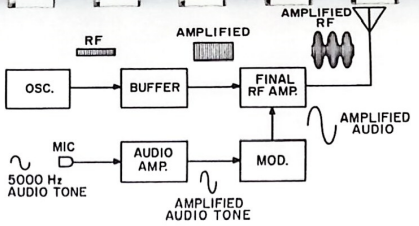
SIMPLIFIED FM TRANSMITTER

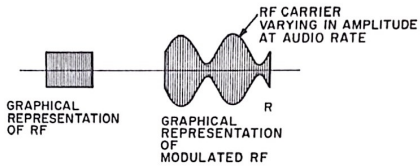


SIMPLIFIED SSB TRANSMITTER

CHECKPOINTS

This transmitter has a speech amplifier, just like our simple AM transmitter (for the same purpose . . to build up the audio signal level). This transmitter also has an oscillator and buffer stage. As before, these stages generate an RF signal, then amplify it. Now we come to a new block . . . the **balanced modulator**. Its job is to "balance out" the carrier frequency signal. We won't get into the deep theory of "why?" here . . . but simply say that the output of this stage is essentially the upper and lower sideband signals which contain the intelligence . . . and a greatly reduced carrier frequency signal. This reduced carrier "doubled-sideband" signal is then fed to the Band-pass filter . . . where one of the sidebands is filtered out. We now have a "single-sideband, reduced carrier" signal at its output. The mixer and next oscillator feeding it are used to move the frequency of the SSB signal to where we want it in the radio spectrum. In fact an SSB transmitter may have several stages of mixers with their coordinated oscillators in order to arrive at the desired frequency of output. The bandpass filter following the mixer-oscillator further filters the signal . . . and, of course, the RF amplifier builds up the resultant SSB signal to the desired level at its output.




RF CARRIER VARYING IN AMPLITUDE AT AUDIO RATE
GRAPHICAL REPRESENTATION OF RF
R
GRAPHICAL REPRESENTATION OF MODULATED RF

CHECKPOINT:

Since all the transmitters we have talked about "qualify" as systems, answer the following:

1. The A.M., F.M. and SSB transmitters all have two basic types of inputs. Name them.
   The _____
   & the _____

2. The various stages of the transmitters might be summarized as what part of a basic system?
   The _____

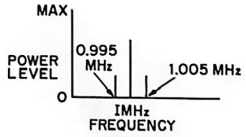
3. The modulated RF signals fed from the "final" RF amplifier to the antenna system might be considered the _____ _____ of the transmitter system.

ANSWERS:
1. The **AC power in** and the **Audio frequency signals.**
2. **Processor**
3. **Output**

Since we have mentioned the term "sideband/s" . . . let's talk for just a moment about them.

If we were to "take a peek" at where the power is being transmitted by an A.M. transmitter . . . we would find that when the RF wave is being amplitude-modulated . . . there is actually more than one frequency present in the transmitted wave. Look at the sketches in column 2 in the appropriate sequence and note what happens when we modulate an A.M. transmitter with a carrier of 1 MHz with a 5000 Hertz sine-wave tone.

Notice in our last sketch, we show that there is not only radio frequency energy at the carrier frequency of 1 MHz, but also some energy present 5000 Hz above the carrier frequency, and 5000 Hz below the carrier frequency. It so happens that when we amplitude-modulate an RF signal . . . we actually cause some new frequencies to be generated. In this case, the "lower sideband" at 0.995 MHz. and the "upper sideband" signal at 1.005 MHz. As you can see, these sideband signals appear above and below the "carrier frequency" by an amount equal to the "modulating" AF frequency. Try the checkpoint!



CHECKPOINT:

1. If a transmitter's carrier frequency is 3.5 MHz, at what frequencies do the upper and lower sidebands appear if the modulated RF stage is being modulated by a 10 kHz. sine-wave audio signal?

USB freq. = _____ MHz.
LSB freq. = _____ MHz.

ANSWER:
USB freq. = 3.51 MHz.
LSB freq. = 3.49 MHz.

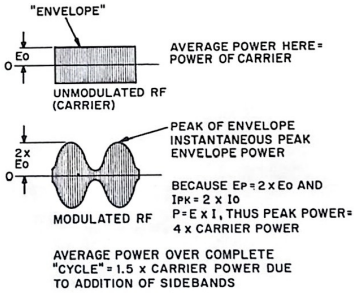
How did you do on that? Do you know how to find the upper and lower sideband frequencies now? I hope so! Since we are on the subject of the modulated wave and transmitters . . . here's something that might be on the test you're preparing for. For an A.M. signal (single-frequency modulated), what are the relative powers of the carrier, sidebands, etc?

Look at the illustrations in column 2 . . . then come back to this column and we'll discuss the important facts.

Without modulation, the power out of the transmitter is the **carrier power** . . . whatever that might be. When we 100% modulate the RF with a sine-wave, single-frequency audio signal . . . the amplitude of the RF wave changes at the audio rate. As we said before . . . we create **sidebands**. Note from the sketch that the peak amplitude of the modulated wave is 2 times the amplitude of the unmodulated carrier. Assuming that the RF is fed to a constant impedance load (50 ohms for example) . . . if we double the E across the load, the current through it must double. Since E is double and I is double, and power equals E x I . . . then we have 2E x 2I . . . thus 4 times the power . . . at the "instant" of peak amplitude of the modulated wave. This business of calculating power at a given instant of time gives us an **instantaneous** power answer. If you were to find the average power in a 100% sine-wave modulated RF wave you would find that there is the carrier power + the power in the sidebands coming from the audio signal . . . the result is 1.5 times the power of the unmodulated carrier. So, briefly listing the important numbers for you to remember . . .

1. Average power of unmodulated RF = carrier power
2. Average power of 100% modulated RF = 1.5 times carrier power.
3. Instantaneous peak power for 100% modulation = 4 times carrier power.

By the way . . . it is possible to see this "graphical" representation of an A.M. signal by looking at the output of an A.M. transmitter using an oscilloscope. The oscilloscope is an instrument that you will probably want to put high on your list of test equipment you should obtain.

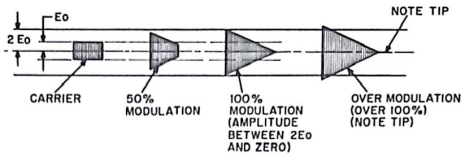

"ENVELOPE"
Eo
0
AVERAGE POWER HERE = POWER OF CARRIER
UNMODULATED RF (CARRIER)
2x Eo
0
PEAK OF ENVELOPE INSTANTANEOUS PEAK ENVELOPE POWER
BECAUSE EP = 2 x Eo AND IPK = 2 x Io P = E x I, THUS PEAK POWER = 4 x CARRIER POWER
MODULATED RF
AVERAGE POWER OVER COMPLETE "CYCLE" = 1.5 x CARRIER POWER DUE TO ADDITION OF SIDEBANDS

Since we mentioned scope patterns . . . there is one scope pattern regarding A.M. signals that the FCC likes to include in their test. It is the **Trapezoidal** pattern . . . which very neatly shows the percentage of modulation and the linearity of an A.M. signal. The thing to learn here is how to recognize the percentage of modulation by means of the trapezoidal pattern.

Study the sketch until you think you understand how to interpret this trapezoidal pattern . . . should you see it on your FCC test.

Previously we had only mentioned 100% modulation. Naturally, if the audio signal (the modulating signal) is not of great enough amplitude, it will not cause the modulated stage voltage output to vary to twice the level of Eo . . . so you get less than 100% modulation. If the audio signal fed to the modulated stage is too great . . . it will cause the amplifier to distort the signal, and create unwanted spurious frequency radiations . . . so the FCC says . . . **DO NOT MODULATE OVER 100%.**

O.K. Time for another checkpoint.



TRAPEZOIDAL WAVEFORMS

CHECKPOINT:

1. Since the average power of a 100% modulated A.M. signal is 1.5 times the carrier power . . . where did the extra power come from?

   _____

   _____

2. For a 100% modulated A.M. signal . . . what is the instantaneous peak power compared to the carrier power?

   _____

3. In the space at the left draw the trapezoidal waveforms for a 50% modulated A.M. signal and for a 100% modulated A.M. signal.

50% MODULATION

ANSWERS:

1. **From the sidebands** . . . which were created because of the modulating signal audio power.
2. Peak Power = **4 times the carrier power.**
3. See left.

For a single-sideband transmitter (SSB), the carrier is "suppressed", or greatly reduced, so to find the "Power Input" to the final amplifier in an SSB system, one must multiply the DC plate voltage applied to the stage by THE HIGHEST VALUE OF CURRENT registered on the plate current meter for the stage. As you recall . . . for the regular A.M. signal, the AVERAGE plate current didn't vary with modulation . . . but in an SSB transmitter . . . the plate current varies greatly with modulation . . . and is at a very low level when there is no modulation present.

CHECKPOINT:

If an SSB transmitter is being modulated so that the highest deflection of the plate current meter in the final amplifier stage is indicating 300 mA and the plate voltage is 2000 volts . . . what is the DC input power to the "final"?

Input Power = _____ watts

ANSWER:
600 watts

INFORMATION

Another area of information we want to mention before leaving the broad subject of transmitters . . . and that is the topic of **neutralization** of RF amplifiers.

If you will think back a little, you will remember that we said an oscillator was simply a "hot rod amplifier". As you can recall . . . it really boils down to the fact that any amplifier that has some feedback "in proper phase" can become an oscillator.

It's undesirable for an amplifier to function as an oscillator when the circuit is to be used as an amplifier. In a transmitter . . . if an amplifier goes "into oscillation" . . . it will generate spurious radiations that can interfere on the radio bands . . . not to mention it causes loss of efficiency and other unwanted side effects.

The method that is used to minimize the effects of unwanted feedback in an RF amplifier is called **neutralization**.

Generally, this unwanted feedback from output circuit back into input circuit is due to the "interelectrode capacitance" between plate and grid of a tube.

To neutralize the EFFECTS of this C_{gp} . . . there are several methods of "balancing out" this undesired feedback. The main thought here is that a signal path must be provided which will ALSO feedback a signal from output to input . . . but will cancel the effects of the undesired feedback signal. The most common way of achieving this is with a **NEUTRALIZING CAPACITOR**. The two basic methods . . . from which other methods are derived, are shown.

Plate *(sometimes called Hazeltine)* **neutralization** is characterized by the C_n being connected from the "bottom" of the plate tank *(LC) circuit and the grid.* ***Grid*** *(sometimes called Rice)* **neutralization** *is identified by the* C_n being connected directly at the plate . . . *and going to the bottom of the grid inductor.*

You are not required to be able to "draw these circuits from scratch". You should be able to recognize them . . . or be able to draw in the neutralizing capacitor between the two correct points if you are provided a drawing with everything but C_n.

REFERENCE & DATA

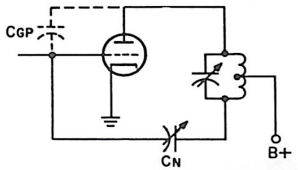
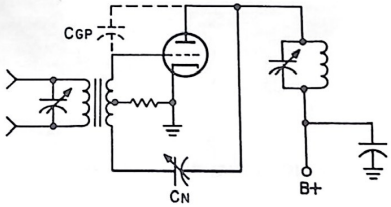


PLATE (Hazeltine) NEUTRALIZATION
(CN = from bottom of plate tank directly to grid)



GRIDE (Rice) NEUTRALIZATION
(CN = directly from plate to bottom of grid circuit inductor)

CHECKPOINTS

CHECKPOINT:

1. For plate neutralization of an RF amplifier, the neutralizing capacitor is connected between _____
_____
_____

2. For grid neutralization of an RF amplifier, the neutralizing capacitor is connected between the _____
_____
_____

ANSWERS:

1. **Between "bottom" of the plate tank and the grid of the tube.**

2. **Between the plate of the tube and the bottom of the grid inductor.**

One final bit of learning before we move on to receivers.

FCC likes to ask a question on their test regarding the **Plate Efficiency** of final RF amplifiers. It is really quite simple to calculate, so let's "clue you in" on this one.

Whenever "efficiency" of a stage is mentioned, it generally refers to how much power is put in to the stage compared to how much power is delivered to the load at the stage's output. So, for RF amplifiers, to find the efficiency in percentage . . . all that's required is calculate the DC power input to the stage (plate voltage times plate current) . . . determine by some means how much RF power is being delivered to the load (antenna or other load) . . . then determine what percentage of efficiency is transpiring.

Example: If the final RF amplifier in a transmitter delivered 70 watts of RF power to a "dummy load" (a resistive load in place of an antenna, for example), as measured by an RF meter . . . and the DC power input to the stage were 100 watts (that is, the product of plate voltage times plate current = 100 w) . . . the efficiency would be 70 percent.

THE FORMULA FOR PLATE EFFICIENCY

$$\text{Eff.} = \frac{P_{OUT}\ (RF)}{P_{IN}\ (DC)} \times 100$$

Where: Eff. = efficiency in %
P_{OUT} = RF or AC power to load
P_{IN} = DC power input to stage

CHECKPOINT:

What is the plate efficiency of a transmitter final RF stage if its plate voltage is 1000v, its plate current is 400 mA and the RF output power is measured as 300 W?

ANSWER:
DC input power = 1000v x 400 mA. = 400W
AC output power = 300 W.

Efficiency therefore = 300/400 x 100
Efficiency = .75 x 100 = 75%.

THE RECEIVER

One half of a communications system is the transmitter . . . which we have been discussing for the past few minutes . . . the other half is the receiver. Let's see how this second half of the communications system works.

Because most receivers use the **superhetrodyne** system of receiving . . . we'll spend our time discussing the key facts you need to know about this type.

In electronics the term **heterodyne** means to mix two signals together to produce new frequencies. These new frequencies will be the sum and difference of the two frequencies. For example, if we **mixed** a 1000 kHz signal and a 1455 kHz signal . . . the "new" frequencies would be 1455 + 1000 kHz (2455 kHz) and 1455 - 1000 kHz (455 kHz). These would be in addition to the two original frequencies of 1000 and 1455 kHz.

INFORMATION

The **superheterodyne** receiver takes the incoming signal . . . mixes it with a signal developed by an oscillator stage in the receiver . . . and produces new frequencies . . . from which ONE band of frequencies is selected by tuned circuits to be passed along to the rest of the receiver circuits for further "processing".

This "new" frequency (really band of frequencies in which there is the "carrier" and the "sidebands" in which the intelligence is contained) is generally chosen to be much lower in frequency than the transmitted signal . . . but much higher than the audio range . . . or "super" audible . . . hence the term "superheterodyne" receiver. The reason for Mixing and producing this new frequency (called the **Intermediate Frequency**) is it is much easier to build stable, high-gain amplifiers at lower frequencies. Also, if we design our receiver oscillator so that we tune (change) its frequency at the same time we are tuning to different stations . . . we can make it so that the **Difference Frequency** between the **local oscillator** signal and the incoming RF signal is always the same. This means our **intermediate frequency** (I.F.) amplifier stage(s) can be "fixed tuned" . . . and we don't have to "track" several stages' tuning mechanisms to make the receiver work. Do the Checkpoint.

REFERENCE & DATA

CHECKPOINTS

CHECKPOINT:

1. The term **heterodyne** means: _____

   a. To mix two signals together to produce new signals.
   b. To separate two signals in order to isolate them.
   c. Neither of the above.

2. The new frequency (or band of frequencies) produced by **mixing** action in a superheterodyne receiver is called the _____ frequency.

3. This new frequency is usually (lower? higher?) _____ than the "incoming" RF from the radio station . . . but is higher than the _____ range.

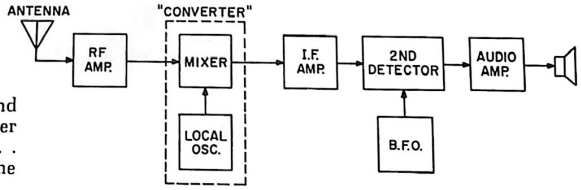
ANSWERS:

1. **A**
2. **Intermediate frequency**
3. **Lower than RF incoming higher than audio**

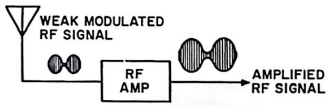
All right! turn on your "biological computer" (your brain) and *let's take a mental walk through a typical superheterodyne receiver and follow the signal as it travels from the receiver antenna . . . through the various stages of "processing" . . . on out to the speaker and of course, you know what happens from there on.*

Let's think our way through the "block diagram" of a receiver at the right. We'll try to mention the key job (or processing) each block performs in this functional "system" . . . the receiver.

First, the **RF amplifier** does just what its name implies . . . it builds up the RF signal coming from the antenna.

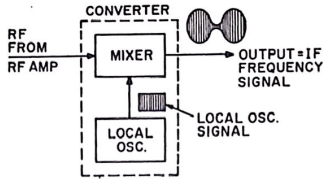


BLOCK DIAGRAM OF SUPERHETERODYNE RECEIVER



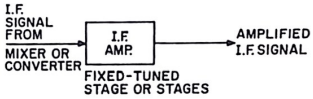
RF AMPLIFIER–BUILDS UP WEAK SIGNALS

This next block uses a name we haven't mentioned before . . . the ***Converter.*** *You will notice that in this block are two functions: the* **oscillator** function . . . sometimes referred to in the "superhet" receiver as the **local oscillator** . . . and the **mixer** function. As you have probably already figured out . . . the oscillator develops the signal which is to be mixed with the incoming signal from the radio station in order to produce the new frequency we call the **intermediate frequency** (I.F.)

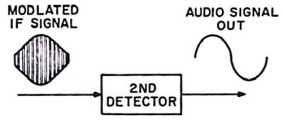


As you see, the mixer is getting two inputs: the oscillator signal and the RF fed from the RF amplifier. These two signals are "mixed" in the mixer . . . and the output of the mixer is the I.F. frequency (plus the others we mentioned earlier . . . however, the tuned circuits "pass along" only the I.F. signals). Many times one stage will perform the oscillator **and** mixing function. In this case it is called the **CONVERTER** stage. This is because it **CONVERTS** the incoming signal to a new frequency.

So far the incoming signal from the radio station has been amplified by the RF amplifier stage . . . then converted to an I.F. frequency by the oscillator and mixer (or converter stage).

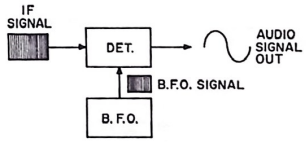


Tuned circuits (called I.F. transformers) now select this I.F. signal from all the various signals present at the output of the mixer or converter . . . and pass it along to the I.F. amplifier stage(s). The job of the I.F. amplifier section is to build up the fairly weak signal at its input to a much stronger signal at its output.



This amplified "i.f." signal is then fed to a **DETECTOR** whose job it is to **detect** the audio information from the modulated I.F. signal. This stage is sometimes called the **second detector** (in the superhet receiver) because the converter stage is also changing the nature of the signal . . . and is sometimes called the "first detector". This "2nd detector" processes the modulated I.F. signal and **demodulates** it. Remember, at the transmitter . . . we modulated the RF in order to put the audio intelligence on the signal . . . O.K., in the receiver, the detector **demodulates** the signal to recover the audio information (removes the RF signal, leaving only audio).

At this point in the system there is one block that appears in many communications receivers that doesn't appear in your regular A.M. table radio at home.



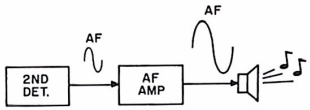
Notice the block labeled **B.F.O.** This means **beat-frequency-oscillator.** For receiving code signals . . . or for receiving single-sideband-signals (SSB), this stage is absolutely necessary. For example when receiving code, the BFO signal is mixed with the I.F. signal to produce an audible tone (when the two signals are "beat" together . . . and their difference frequency is in the audio range). A BFO is also used for a special type of detector circuit used in SSB receivers. For now, simply remember that the BFO stage is used for CW reception to produce an audio tone (rather than you simply hearing an "airy" sound every time the sender closes his key and transmits RF . . . and silence when the key is up because no RF is being transmitted) . . . and is used in conjunction with a special SSB type detector (called a product detector).

INFORMATION

Out of the 2nd detector circuit comes our long-awaited audio signal. This signal is then amplified by the audio amplifier stage(s) and built up to drive the speaker.

There . . . that trip through the receiver wasn't so bad after all, was it? Try the checkpoint to see if you picked up the most important facts.

REFERENCE & DATA



CHECKPOINTS

CHECKPOINT:

1. What stage in a receiver demodulates the modulated I.F. signal? _____
2. What stage(s) in a receiver changes the incoming signal(s) to a new frequency range? _____
3. Which stage or stages in a receiver build up the I.F. signals to a higher level? _____
4. Which stage in a communications receiver is needed in order to produce an audio tone for C.W. reception? _____
5. Which stage in a receiver builds up the incoming RF signal to a larger amplitude signal? _____
6. What is the job of the audio amplifier? _____
7. What stage(s) in a superheterodyne receiver is sometimes referred to as "fixed-tuned" stages? _____

ANSWERS:

1. **2nd Detector** (or **detector**)
2. **Converter** (or **mixer & local oscillator**)
3. **I.F. amplifier**
4. **B.F.O.** (beat-frequency-oscillator)
5. **R.F. amplifier**
6. **Builds up audio to level needed to drive speaker.**
7. **I.F. amplifier stage(s)**

How did you make out? Learning the block diagram of ANY system will help you understand it. It sort of gives you "pegs to hang your thoughts on". Makes it easier for you to "think" your way through a system. It gives you what someone has jokingly called the "GO-ZINTA-GOZOUTA" theory. Meaning: it helps you to learn what signal or input "goes into" a stage, or functional block . . . and what signal "goes out of" that stage or block. Once you have learned a system's block diagram and what type signal should go into each block and come out of each block . . . you've gone a long way toward understanding how the system works. It also helps in practical troubleshooting of electronic systems. For example, if you know that all the appropriate signals are arriving at the input/s of a stage . . . but the output is missing or abnormal . . . you are pretty sure that the trouble is in that stage . . .

Reviewing and summarizing:

1. The RF signal arrives at the receiving antenna.
2. It is fed to either the converter stage if there is no RF amplifier . . . or the RF amplifier stage.
3. Assuming an RF amplifier stage (which most communications receivers do have) . . . the amplified RF signal is next fed to the "converter".
4. The converter . . . or oscillator and mixer stages, converts the RF signal to I.F. signals.
5. The I.F. signals are amplified by the I.F. amplifier and fed to the "demodulator", or 2nd detector.
6. The detector recovers the audio signal information from the modulated I.F. signal . . . and passes it along to the audio amplifier.
7. The audio amplifier builds up the audio to a level needed to drive the speaker.

ANTENNAS & TRANSMISSION LINES

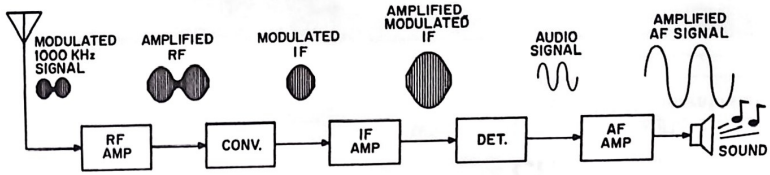
We've been talking about communication systems, including the transmitting and receiving ends of the system. Now let's give you some facts regarding the part of the total communications system which is vitally important at both ends. It is necessary to get the energy from the transmitter . . . and by some means "couple" it into space. In fancy words . . . we need to propagate the radio energy. At the receiving end it is necessary to "couple" this transmitted energy from space . . . into the receiver. The means whereby the radio energy is transferred from the transmitter into a radiated radio wave . . . and from a radiated wave into the receiving system is the antenna and its associated transmission line.

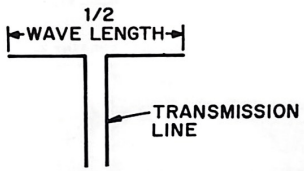
Antenna and transmission line theory, if studied deeply, could fill many books (and does). Our only purpose here is to familiarize you with important facts that will be needed for FCC test and basic general knowledge as a Radio Amateur. Here's an area where we will deviate some from our basic philosophy of understanding everything rather than memorizing cold facts. Because of the complexity of the subject . . . it will be far more efficient for you to remember some "cold facts" using the memory technique along with understanding, where possible.

We'll discuss just two basic types of antennas . . . which are fundamental to many other types.

These two types are: the "half-wave" (often called the Hertz) antenna, and the "quarter-wave" (often called the Marconi) antenna.

EXAMPLE OF SIGNAL PROCESSING BY "SUPERHET" RECEIVER, ASSUMING INCOMING RF AT 1000 KHz AND LOCAL OSCILLATOR AT 1455 KHz





HERTZ ANTENNA
Sometimes called the "dipole"

MARCONI ANTENNA

INFORMATION

If you'll take your "memory banks" back quite a few pages . . . into the Novice chapter, you will remember we talked about radio energy and electrical energy traveling at the speed of light . . . which is approximately 186,000 miles per second . . . or, 300,000 meters per second. This is how fast radio energy travels in "free space". We also mentioned that a wavelength is the distance that a given frequency of energy would travel during the time of one cycle (1 Hertz) of that frequency. You will recall that the formula for wavelength (symbolized by the Greek letter lambda λ) was the velocity of the energy divided by the frequency involved.

Try the checkpoint!

REFERENCE & DATA

$$\lambda = \frac{3000{,}000}{30 \text{ MHz.}} = 10 \text{ meters}$$

CHECKPOINTS

CHECKPOINT:

1. By what means does radio energy "get transferred" from a transmitter into space?

   _____

2. What is the wavelength in meters of a frequency of 15 MHz.?

   λ = _____ meters

3. The higher the frequency . . . the (shorter? longer?) the wavelength?

   _____

ANSWERS:
1. **antenna & its transmission line**
2. **20 meters**
3. **shorter**

I'll bet you are ahead of me already regarding why the half-wave and quarter-wave antennas are so-named. Yep! It's because their physical length is about 1/2, or 1/4 wavelength, respectively.

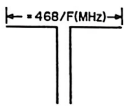
Because antennas are normally reasonably close to the ground, surrounding buildings, trees and objects . . . there is a "fudge-factor" involved when coming up with a useable and practical formula for determining the length of these antennas. It has been found that this "fudge-factor" is about 5% . . . that is, the antenna will end up being about 5% shorter than it would be if we used "free space" numbers for determining its length.

For example: the "free-space" formula for a Hertz (1/2 wave) antenna is:

The number that we'll call the "magic number" for a practical situation is:

In words, that says that the length of a half-wave Hertz antenna equals the "magic number" 468, divided by the frequency in MHz. The answer will be in FEET. See, we did all the converting from meters to feet for you. MEMORIZE THIS FORMULA! Try the problem in the checkpoint.

HERTZ ANTENNA LENGTH IN FEET



$$\text{Antenna Length} = \frac{492}{\text{F (Mhz)}}$$

$$\text{Hertz antenna length} = \frac{468}{\text{F (Mhz)}}$$

CHECKPOINT:

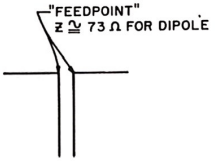
What is the proper length, in feet, for a Hertz antenna which is to operated at approximately 14.3 MHz. _____

_____ FEET.

ANSWER:
Approximately 32.72 feet.

Naturally, the Marconi 1/4th wavelength antenna would be approximately half the length of a Hertz.

Let's mention right here that it is common to find the Hertz antenna oriented horizontally, i.e., suspended with its length parallel to the ground, and to find the 1/4th wave Marconi oriented vertically with respect to ground. Sometimes you will find the 1/2 wave Hertz vertically mounted . . . but probably a larger percentage of the time this type antenna is horizontally mounted. The Marconi is almost always vertically mounted.



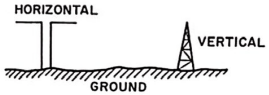
Let's briefly discuss the key characteristics of each of the two types of antennas. First let's mention the **feed-point impedance**. This is the impedance at the point where the **transmission line** connects to the antenna.

Hertz (often called the **dipole**) normal feed point impedance = 73 ohms.

Marconi (1/4th wave antenna) normal feed point impedance = about 36 ohms.

As mentioned earlier . . . the Marconi is normally **vertically polarized**. The Hertz or dipole is most frequently **horizontally polarized** . . . but can be vertical if desired.

Incidentally, the term "polarization of an antenna" we do not need to delve into deeply. You can assume that an antenna that is oriented horizontally with respect to ground is "horizontally polarized" . . . one that is vertical is "vertically polarized". This technical term refers to the direction that the "radiated fields" from an antenna are oriented with respect to earth.



The vertical 1/4th wave antenna has a "low-angle" of radiation. This is good for long-distance transmission.

Try the checkpoint to see if you've learned the key characteristics of the 1/2 wave and 1/4 wave antennas.

CHECKPOINT:

1. What type antenna has a feed-point impedance of approximately 73 ohms?

   _____

2. Which antenna type would you calculate the physical length of by the formula 468/F (MHz)?

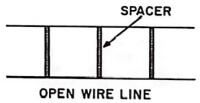
   _____

3. What type antenna has a "low-angle of radiation"?

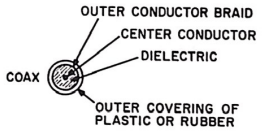
   _____

ANSWERS:
1. **Hertz (or half-wave dipole)**
2. **Herta (dipole, half/wave)**
3. **Marconi (1/4th wave)**

O.K. so much for the "radiators" of radio energy, the antennas . . . let's look for a moment at the transmission line, whose job it is to transport the radio energy to . . . or from the antenna.



Transmission lines come in a number of forms. Everything from just plain "open wires" with insulating spacers to keep the distance between the wires uniform throughout its length . . . to TV type "twin-lead", which uses plastic encapsulation methods . . . to "coaxial cable", which consists of a "center-conductor" wire, around which there is insulating material . . . then a special webbed conductor material surrounding the center-conductor and separated by the insulating material. All if these perform the same function . . . that is transporting the radio energy from one point to another.



INFORMATION

Each of the above-mentioned types have certain characteristics . . . but let's just mention the main ones to remember.

Each has its own impedance characterisitc. This is called its **characteristic impedance** and is symbolized by: Z_0. This is also sometimes referred to as its **surge impedance**. Don't get frightened by all these terms . . . just be able to recognize them if you see them again. The things that effect the Z_0 of a transmission line really boil down to just a couple of items. Namely, the spacing between conductors . . . and the characteristic of the insulating or dielectric spacing material.

One formula that you should at least be able to recognize if you see it again relating to the impedance of an air-insulated parallel conductor transmission line. The formula is:

Without going into a deep discussion of this formula . . . you can see that if the spacing between conductors for the "open-wire" transmission line is increased . . . the Z_0 will increase. Also, the smaller the radius of the conductors . . . the higher the Z_0.

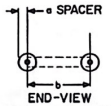
You, as a radio amateur, may want to construct an "open-wire" transmission line . . . but chances are pretty good that most of the time you will buy ready-made transmission line in the form of "coaxial cable". Cables are designed with various values of Z_0 . . . so normally, you would simply buy coax (as it is called for short) that is approximately the Z_0 you need . . . and which can handle the amount of power used.

While we are on the subject of impedances in transmission lines and antennas . . . let's talk about a very important subject to radio amateurs. The subject is **standing-wave ratio**, abbrieviated SWR. If you listen on the amateur bands much at all . . . you will hear hams using this term frequently.

If we terminate a transmission line (no matter which type) whose characteristic impedance (Z_0) is 73 ohms, with a dipole whose feed-point impedance is 73 ohms . . . we would say that there is an **impedance match** between the two. In real life, if we did this . . . virtually all the electrical (radio) energy traveling along the transmission line would be transferred to the "load" . . . in this case the antenna. When the impedances are matched as in our example . . . the SWR (standing-wave-ratio) would be considered "1". You'll see why in a moment.

When there is an impedance "mismatch" between "source and load" . . . we cause a situation where some portion of the energy is not absorbed by the load but is "reflected".

REFERENCE & DATA



END-VIEW
OPEN-WIRE LINE

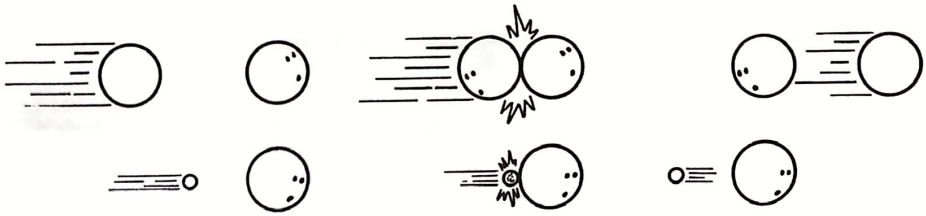
$$Z_0 = 276 \log b/a$$

where: Z_0 is the characteristic impedance
b = the center-to-center distance between conductors
a = radius of conductor
log = logarithm (base 10)

CHECKPOINTS

An everyday type example of reflected energy might be as follows:

If I were to roll a bowling ball across the floor into another bowling ball which was just sitting there . . . when the rolling ball hit the still one . . . most of the mechanical energy would be transferred to the still one. The rolling ball would stop, and the still one (which we'll call the mechanical load) would roll because the energy is efficiently transferred from the source (the rolling ball) to the load (the still ball) because there was a "mechanical impedance match". If, however, I were to throw a golf ball at the sitting bowling ball . . . most of the energy would be reflected in the form of the golf ball bouncing back . . . and very little absorbed by the load (the bowling ball) . . . because there was a TERRIBLE MECHANICAL IMPEDANCE MISMATCH.



The same type thing happens in an electrical circuit when there is an electrical impedance mismatch. In such a case of mismatch, the reflected wave (energy traveling from the load back toward the source) meets the oncoming "forward", or incident wave . . . and lo and behold . . . we cause what are called **standing waves**. These are created by the oncoming or forward energy waves meeting the reflected waves . . . and having an adding and cancelling effect in various positions along the transmission line. Hence, we produce **standing waves** where electrical values are maximum at one point in the line . . . but minimum 1/4th wavelength away.

THE STANDING WAVE RATIO, or SWR as it's called, is the ratio of maximum voltage to minimum voltage . . . or maximum current to minimum current . . . along the transmission line. A rough analogy of the creation of standing waves is to think of what happens if you create a "string" of waves in your bathtub by wiggling your hand at a constant rate. When the little wave hits the side of the tub and bounces back toward the middle of the tub . . . it meets the next oncoming wave . . . and we create the equivalent of a "standing wave" effect in the water.

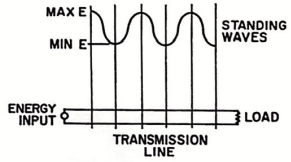
The important thing to remember about standing waves is that the better the impedance match between the antenna and transmission line . . . the lower the standing-wave ratio . . . and the more of the energy is transferred to the load and used. If we have an impedance mismatch of 2:1, the SWR (standing-wave ratio) will be 2.

Example: if the dipole antenna Z is 73 ohms and we try to feed it with a transmission line whose characteristic impedance is 36.5 ohms . . . the SWR = 2.

SWR can be calculated by the following ways:

When impedance is MATCHED . . . SWR = 1, and the current and voltage along the line is at a uniform value. (Except for minor loss along the line.)

Try the checkpoint!



SWR = I max/I min (along the line)
SWR = E max/E min (along the line)

Also, SWR = ratio of the impedance mismatch.

One other term we will mention so you won't be "shaken" if it appears on a test is the term **feedline**. This term is sometimes used instead of the word transmission line. It means the same thing. Its the line that "feeds" the energy to the antenna.

CHECKPOINT:

1. If an antenna feed-point impedance is 100 ohms and we are feeding the antenna with a transmission line whose Z_0 = 25 ohms . . . what is the SWR along the line? _____

2. Transmission lines may come in several forms. Among them are: the open-_____ line twin-_____ and _____ cable.

3. If we double the spacing between the conductors of an open-wire transmission line . . . what will happen to its characteristic impedance? . . . will it increase, decrease or remain the same? _____

4. One other name that is sometimes used for the term "characteristic impedance" is? "_____ impedance". The symbol used to represent characteristic impedance is: _____

5. If the minimum current value points along a transmission line where there is an SWR of 3, is 1 ampere . . . what would be the maximum current value points along the line? _____ A.

ANSWERS:

1. **4**
2. open-**wire**; twin-**lead**; **coxial** cable
3. **increase**
4. **surge**-impedance; Z_0
5. 3 amperes

We've been discussing the communications system which involves the transmitter . . . the transmission line and antenna . . . the receiving antenna . . . and the receiver. You may wonder why the amateur radio bands have been allocated by the FCC as "little chunks" of frequency spectrum at a number of different places (frequencies), rather than simply alloting amateurs one great big band of frequencies. Well, we don't know all the reasons . . . but one reason very well may be that different frequencies have different **propagation characteristics**. Some frequencies will **propagate** over long distances at certain times of the day and/or **sunspot** cycle . . . others will travel long distances at night, etc.

Right here we are going to list some generalizations regarding the most used ham bands below 30 MHz. It would be helpful for you to try to remember the main ideas presented . . . however, we don't expect you to become a **propagation expert**. You may want to keep these generalities in mind for your own operating convenience . . . and there is a possibility that some of this information might need to be "recognized" on a multiple-choice type FCC test.

Study the chart for these important generalities. When you think you have them in mind, try the little checkpoint!

GENERAL PROPAGATION CHARACTERISTICS Below 30 MHz

1.8 MHz band
- short distance during day
- can sometimes go long distance during night
- high atmospheric noise (especially at night)

3.5 MHz band
- short distance during day
- long distance possible at night

7.0 MHz band
- somewhat longer range during day than 3.5 MHz
- long distance possible at night

14.0 MHz band
- long distances possible in daytime
- long distances also possible at night
- not too good for local "ground wave" work
- most propagation by "sky wave"

21.0 MHz band
- similar to 14.0 MHz band

28.0 MHz band
- line of sight transmission common
- long distances possible under certain sun-spot cycle conditions

CHECKPOINT:

1. To work a fellow ten miles from your shack . . . would you tend to use frequencies of 7.0 MHz and lower . . . or above 7.0 MHz? _____

2. Generally speaking, the higher frequency bands enable long distance daytime communication (better than, poorer than) _____ the lower frequency bands.

ANSWERS:

1. **lower than 7.0 MHz**
2. **better than**

SMORGASBORD!

O.K. Fasten your seatbelts! We've come to the portion of the book where we will expose you to a big variety of facts . . . some related . . . some not . . . for you to glean for test preparation purposes. It would be impossible to go into detail on all these . . . but we want you to at least get a glimpse of these facts so you'll recognize them if they appear on the FCC exam.

Our first course in the Smorgasbord deals in the general area of significant terms and definitions.

The FCC has certain designations for the various types of emissions, or transmissions. Two broad categories of classification are . . . the type of modulation used (amplitude, frequency or phase and pulse), and the type of transmission (CW, phone, TV, etc.)

The type of modulation is indicated by the letter at the beginning of the FCC designation and the number denotes transmission mode . . . for instance A3 transmission is amplitude modulated phone . . . F3 is frequency modulated phone . . . and pulse modulated transmissions use the prefix P.

We don't expect you to memorize the whole chart at the right . . . but you should look at it until you think you could recognize the definitions if you saw them. We'll point out in a couple of minutes which designations you will see most often as a radio amateur.

Wow! Looks like a lot of info! It is . . . but the main ones to be aware of are A0, A1, A3, A3J and F3. A0 is simply unmodulated and unkeyed carrier. A1 = keying of an unmodulated carrier to send code. A3 = standard A.M. phone; A3J = single-sideband phone (which is SSB—suppressed carrier AM). F3 is F.M. phone operation. That's not so bad, is it? You'll get a chance to see if you can recognize some of these designations when you take the sample "multiple-choice" FCC type test we'll give you at the end of this chapter.

Next on our "variety show" is the term **TVI**. This means **television interference.** This can be in many forms . . . but basically is disruption of the picture and/or sound on a TV receiver due to electrical radiation from outside sources. Some sources of TVI can be: machinery (such as diathermy machines), electric ovens, amateur transmitters and so on. If the transmitter has good shielding, and uses good engineering practice in design (by-passing, shielding and filtering), then the problem probably lies with the receiver. Two good methods of at least decreasing the possibility of TVI are: make sure the transmitter has a good "low-pass" filter in its output circuit (to eliminate frequencies which might appear in the TV channels . . . and, on the receiver that is being troubled . . . properly install a "high-pass" filter (which will reduce the strength of any signal from a nearby amateur transmitter).

Checkpoint.

Designations for Types of Transmissions

0 = absence of modulation (just RF carrier)
1 = Telegraphy without using a modulating tone (unmodulated C.W.)
2 = Telegraphy in which an audio tone is keyed on and off with the carrier (tone-modulated C.W.)
3 = Telephony (including broadcasting)
4 = Facsimile (sending pictures, etc., by radio)
5 = Television (visual portion of transmission only)
6 = Four frequency diplex-telegraphy
7 = Multichannel voice-frequency telegraphy
9 = Cases not covered by 0-7

Other special designations regarding transmissions are:

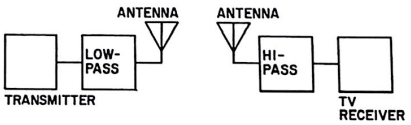
Suffix A = single-sideband, reduced carrier
H = single-sideband, full carrier
J = single-sideband, suppressed carrier

B = two independent sidebands
C = "vestigial" sideband (one sideband partially suppressed as in a TV transmission)

For Pulse type transmissions, the following:

D = amplitude modulated pulse transmission
E = width (duration) modulated pulse transmission
F = phase (or position) modulated pulse transmission
G = code-modulated pulse transmission

Note: these designations are used as "suffixes", for example A3J = amplitude modulated phone using single-sideband, suppressed carrier transmission.



CHECKPOINT:

1. What does TVI mean? _____

2. What can be done at the transmitter end to reduce the possibility of TVI, besides good circuit design of the transmitter? _____

3. What can be done at the receiver to reduce the effects of any possible TVI? _____

ANSWERS:
1. **television interference**
2. install a "low-pass" filter
3. install a "high-pass" filter

Another term you might "run into" is the term **maximum plate dissipation**. This is used in reference to amplifier tubes . . . and normally relates to the final high-power amplifier tube(s) used in the output stage of transmitters.

Earlier we mentioned **plate efficiency** of tubes, and stated that this is the percentage of DC input power to the tube that actually becomes useful AC output power. What happens to the difference in power between the DC plate input power and the AC output power? As you might guess . . . it must be "dissipated" by the plate of the tube. The rating that tells how much power can safely be dissipated by a given tube's plate is called its **MAXIMUM PLATE DISSIPATION**. Of course this is related to how much heat the plate can dissipate. Some factors that influence this are: the physical size of the plate area . . . whether the tube has a fan blowing on it . . . etc. The larger the plate area and the better the cooling system . . . the higher the maximum plate dissipation rating. Try the checkpoint!

CHECKPOINT:

If a transmitter output tube is being operated so its DC plate input power is 1000 watts and its output power is 700 watts . . . what is the minimum "**Maximum Plate Dissipation** the tube should have without "burning up the tube"? _____ W.

ANSWER:
At least **300 watts.**

You will often hear "Hams" use the term **harmonic** or **harmonics**. What do they mean? This refers to a multiple of any given frequency. For example, the second harmonic of 1000 Hz is 2000 Hz. The fourth harmonic of a radio frequency of 1 MHz = 4 MHz and so on.

INFORMATION

When dealing with radio frequencies, you sometimes hear someone talk about **skin effect**. This refers to the fact that high frequency electrical energy traveling along a wire or conductor tends to concentrate its current flow on the outside surface of the conductor . . . or on its "skin". This is due to the way the "induced counter-emf" is distributed throughout the cross section of the wire . . . so there is less opposition to RF currents on the outside of the conductors. This phenomenon of the current traveling along the outside surface of the conductor is called skin effect.

Another rather important term we'll mention in our "smorgasborg" of terms is the decibel, abbreviated dB. This has to do with the comparative power levels of two signals. The mathematical formulas that you should recognize for this are:

O.K. Let's try a checkpoint on our variety of important terms.

REFERENCE & DATA

dB (gain, or loss in decibels) =

$$10 \log_{10} \frac{P_2}{P_1}$$

where:
$\log_{10}$ means logarithm to the base 10.
P_2/P_1 means the ratio of the higher power level to the lower power level.

The dB gain or loss can also be found by comparing voltage levels. Here the formula is:

$$dB = 20 \log_{10} V_2/V_1$$

CHECKPOINTS

CHECKPOINT:

1. What is the third harmonic of a frequency of 2.5 MHz? _____ MHz.
2. Skin effect has to do with the way **low** frequency currents travel along a conductor. True or False? _____
3. When calculating for the number of decibels gain, or loss . . . the term 10 $\log_{10}$ is used in conjunction with the power ratios . . . or, the voltage ratios of the signals being compared? _____

ANSWERS:
1. **7.5 MHz**
2. **False** (high frequency currents)
3. **Power ratios**

You may run into the term ***image response*** *in reference to Superheterodyne receivers.*

Recall that the superheterodyne receiver mixed a local oscillator signal with the incoming RF signal from a station and produced the I.F. frequency to be passsed along to the following stage(s). If you think, you'll remember that this I.F. frequency turned out to be the difference between the incoming RF frequency and the oscillator frequency. Let's suppose that our oscillator was designed to operate 400 kHz ABOVE the incoming RF frequency . . . then, the I.F. frequency would be 400 kHz, right? All right, if we had our receiver tuned to 1000 kHz . . . then the oscillator would be at 1400 kHz. If there happened to be a station at 1800 kHz . . . the difference between it and the oscillator would ALSO be 400 kHz. AHA! There's the **image frequency** we're talking about.

All these nouns and verbs we've been using "boil down" to this: For the superheterodyne type operation . . . there will always be two frequencies that can mix with the oscillator frequency to produce the I.F. frequency difference. One frequency will be ABOVE the oscillator frequency by the amount of the I.F. and the other BELOW the oscillator frequency by that same amount. The undesired one is called the **image-frequency**. This problem is overcome in good receivers by good **selectivity** of the tuned circuits and by the fact that the I.F. frequency is generally high enough that the image frequency signal will be quite far removed from the frequency the tuned circuits are tuned to . . . therefore way down on their response curve.

Way back "yonder" when we talked about amplifiers, we did not mention one special circuit configuration that is sometimes found in amateur transmitters . . . so we'll mention it now. The **grounded-grid** amplifier is sometimes used in the output stage of a transmitter.

Key difference between this and the conventional **grounded-cathode** circuit are that the signal input to this type amplifier is fed at the cathode . . . and instead of the cathode being at signal ground . . . the grid is grounded. One advantage of this type circuit is that because the grid is grounded . . . neutralization is not needed, even at most RF frequencies.

Let's see if you picked up these last tidbits of information.

CHECKPOINT:

1. What is the image frequency of a superheterodyne receiver whose I.F. frequency is 500 kHz. if the desired signal tuned in is at 1000 kHz. and the oscillator is being operated at 1500 kHz.?
   _____ kHz.

2. What is one basic advantage of the "grounded-grid" RF amplifier? _____
   _____
   _____

ANSWERS:
1. **2 MHz.**
2. **No need for neutralization.**

INFORMATION

RULES & REGULATIONS . . . OPERATING PROCEDURES . . . & MISCELLANEOUS INFORMATION

Key fact to learn! What is the maximum permissible plate power input to the final stage of a transmitter as stated by the FCC? The basic answer to this is 1000 watts. This means that the DC plate voltage times the DC plate current must not exceed 1000 watts. There is one exception to this rule . . . and that is on the 1.8 - 2.0 MHz. band the power is restricted to lower levels . . . and is dictated by where you live. If your transmitter does not have accurate meters for measuring these parameters . . . the maximum permissible power is 900 W. The FCC likes amateur stations to use the MINIMUM power necessary to carry out the desired communications . . . so there's less possiblity of interference with other operators.

One other time we mentioned the regulation that the FCC says that the maximum permissible percentage of modulation is 100% . . . but it bears repeating here. Remember that fact! It should be mentioned too, that you cannot modulate even 100% if your transmitter is not capable of producing a "clean" signal with 100% modulation. If a transmitter is well-designed, however, the standard is 100%.

You may be asked why crystal control of transmitters is sometimes used. The basic answer to this is that crystals (used as frequency-determining devices) are capable of much higher Q's than coils and capacitors . . . and hence are more accurate and stable.

The FCC may ask you to know what precautions can be taken to avoid danger from shock from high-voltage electrical circuits. Several of the preventative measures include:

Don't allow high-voltage (including AC line voltage) circuits to be exposed where people can touch them.

Never work on a "live" electronic piece of equipment. This means be sure power is removed when working on equipment which has power supplies, etc., that contain high voltage circuits.

BLEED THE CHARGE OFF all power supply capacitors by shorting from the B+ side to chassis or ground with a "shorting bar". The shorting bar consists of a conductor connected to ground . . . with an insulated handle that you can use to position the other end of the conductor on the "hot" side of B+ . . . thus, discharging any charge on the power supply capacitor(s).

All metal cabinets, chassis, etc., should be permanently connected to a good ground in addition to the normal AC power mains ground.

Time for a Checkup!

REFERENCE & DATA

CHECKPOINTS

CHECKPOINT:

1. What is the maximum permissible DC plate power input to the final stage of an amateur radio transmitter? _____ watts.

2. What is the maximum percentage of modulation that can be used with a well-designed amateur transmitter? _____ %

3. Which type tuned circuit gives better frequency stability and accuracy . . . an LC tank circuit, or a piezoelectric crystal?
_____

4. Name three precautions that can be used (on transmitters for example) to avoid shock. _____
_____
_____

ANSWERS:

1. **1000** Watts
2. **100%**
3. **crystal**
4. Be sure things are enclosed and no high-voltage circuitry is exposed so someone could touch it.
   Discharge capacitors by means of a shorting bar.
   Be sure all equipment is well-grounded.

Here's a comparison that is nice to know, being an amateur operator. How much spectrum (radio frequency spectrum) do various types of transmission take up . . . compared to each other. FCC (and all fellow Hams) like you to use the minimum spectrum space.

A1 transmissions (code) take up the least bandwidth; generally on the order of a few hundred cycles (or Hertz). **A3** transmissions (amplitude modulated phone) take up about 6 kHz of spectrum. This assumes that the audio modulation characteristics of the transmitter limit the audio modulating signal to a maximum frequency of about 3 kHz. (You see it takes 6 kHz because there is an upper sideband 3 kHz removed from the carrier . . . and a lower sideband, 3 kHz below the carrier . . . thus total bandwidth = 6 kHz.) If the transmitter audio circuitry will allow higher audio modulating frequencies to pass . . . then the bandwidth increases accordingly.

For the same modulating frequency, the SSB signal occupies approximately one half the spectrum . . . because one sideband is not transmitted.

Having mentioned that the FCC like amateurs to use the minimum power and radio spectrum possible to carry on communications, let's mention some of the ways of decreasing the amount of interference to other operators. Several good operating procedures to follow:

1. Use the appropriate band for the type communication you are attempting. In other words . . . don't use a band that radiates around the world, when you're just talking across town.
2. Use minimum power necessary.
3. Use minimum bandwidth necessary. (In other words don't use a Hi-Fi audio amplifier to modulate an A.M. transmitter!)
4. Use directional antennas, when possible.
5. Use a "dummy load" when tuning up a transmitter.
6. Monitor the frequency you want to use by listening on the receiver . . . before "tuning up" your transmitter on that frequency.
7. Use common sense.

While we are on the subject of improper operation . . . let's mention a couple of "somewhat associated" facts.

Improper operation of amplifier stages can cause distortion of the desired signal, and possibly damage the stage or stages being incorrectly operated. We told you somewhat earlier in the book that the Class A amplifier stage produced the least distortion. This is true; however, if you have too little bias on the stage . . . or the input signal is too large . . . the grid can be driven positive with respect to the cathode (for vacuum tube stage) and cause the grid to "draw current". This is an undesireable condition for a Class A stage as it introduces serious distortion of the signal.

INFORMATION

In an SSB transmitter, if the final amplifier stages are improperly loaded and/or there is excessive driving signal voltage (input signal), the stage(s) can be driven into a condition of "saturation". This simply means that further increases in driving voltage do not cause appropriate increased power output from the stage . . . in other words . . . the stage is not operating "linearly" and produces distorted output signals. If you were to look at the output of the SSB transmitter on an oscilloscope . . . this condition would be seen as flat-topping of the waveform. This shows that the peaks of the signal are being "clipped" due to the non-linear operation of the amplifier.

We've talked about the Class A amplifier and the "linear" amplifier(s) used in SSB transmitter output stages. Now let's get in one last "tidbit" on amplifiers and mention something about the Class C amplifier.

It is possible to have too much plate current flowing in a Class C amplifier if it is operated incorrectly. Some of the main causes for excessive plate current: incorrect load (too heavy a current drain from the circuit); too little negative bias (improper biasing); the plate circuit tank circuit not tuned to resonance (plate current dip . . . or minimum plate current is present when tuned to resonace); too small an input signal (driving power too small) . . . particularly if grid-leak bias is being used to develop some of the operating bias.

Let's have another little checkup on these miscellaneous facts just before we move on to give you the final bits of information we want to convey before you try your SAMPLE FCC TEST at the end of this chapter.

REFERENCE & DATA

CHECKPOINTS

CHECKPOINT:

1. Which type transmission takes up the least bandwidth in the radio spectrum . . . A1, or A3? _____
2. Which occupies less spectrum or bandwidth . . . A3 or A3J? _____ What is the approximate comparison in bandwidths of these two types of transmissions? _____
3. To help prevent interference on the bands . . . a "dummy load", or "dummy antenna" can be used during what part of the operating procedure? _____
4. Should a class A amplifier stage normally draw "grid current"? _____
5. When observing the output of a SSB transmitter with an oscilloscope . . . is "flat-topping" a sign of good operation? _____
6. Excessive plate current in a class C RF amplifier can be caused by too much bias. True or False? _____
7. When a class C RF amplifier plate tank circuit is tuned to resonance . . . is plate current minimum or maximum? _____

ANSWERS:
1. **A1**
2. **A3J** (about **1/2** as much as A3)
3. **Tune up** of the transmitter
4. **No**
5. **No**
6. **False**
7. **Minimum**

As a radio amateur, you must always be alert to the "edges of the band" you are working, or transmitting on at the time. **YOU ARE RESPONSIBLE to make sure that NONE of your signal "slops" over the edge of the band.** One thing that is very important to keep in mind is that all the equipment you operate has "tolerance" ratings. For example, if you are using crystal control of your transmitter frequency . . . the crystal has a tolerance rating . . . and you must be sure not to get closer to the edge of the band than the amount of frequency which the crystal can be "off" (and still be within its tolerance rating). This is true of variable frequency oscillators, frequency meters for measuring frequency, etc. NEVER operate closer to the band edge than the tolerance of your equipment would dictate as being safe!

Since we are talking about "legal" operation procedures . . . let's pass along another operating fact you will be responsible for as a Ham.

Certain countries around the world have what is called a **third party agreement** with the U.S. This is simply an agreement between the countries which authorizes the exchange of messages BY AMATEURS on behalf of persons OTHER THAN the licensed operator(s). International law PROHIBITS "third party traffic" between countries that do not have in effect this "third party agreement". Most countries with which the U.S. does not have that agreement will still allow communication between the LICENSED OPERATORS themselves . . . but NO traffic handling. There are several countries in the world, however, where NO COMMUNICATION is allowed whatsoever. You must keep abreast of these via the FCC and/or normal Amateur Radio publications. These lists of countries that allow 3rd party traffic . . . those that don't . . . etc., change from time to time . . . so it's your duty as a Ham to keep abreast of the current status.

Since you have . . . or hope to have your own "Ham shack" and certainly have equipment in it you want to take care of . . . as a "finale" we will mention several precautions you can take to protect your station equipment from electrical storms.

As you know . . . lightning can be devastating to anything it "hits" . . . or even things nearby a hit. It is obvious that the part of a ham station that is most prone to invite a lighting stroke is the antenna system. Many times the amateur antenna will be the highest metal object around . . . so watch out! The main way of defending your shack and antenna system is to have an **antenna grounding switch**. Also, you can disconnect your equipment from the antenna when not in use . . . PLUS . . . ground the antenna. In this way if lightning strikes, it has a low resistance path to ground and will not likely cause any permanent damage. BE SURE YOU HAVE A GOOD GROUND CONNECTION! A poor one can sometimes be worse than none at all. Another method that is not quite as good, is to use a "lightning arrestor" (a special spark-gap mechanism).

Here's the time you been working toward, and waiting for! Time for that sample FCC type EXAM to see if you're ready to visit the FCC office and get your General Class License. I hope you haven't forgotten to keep working on your code . . . as they will give you the code test FIRST. If you pass it . . . then they will let you take the written exam. You will recall that the requirements are that you pass a RECEIVING and SENDING code test at 13 words-per-minute, and, the passing of a 50 question "multiple-choice" type written exam. The code receiving test lasts 5 minutes . . . of which you must copy at least 1 minute **with no errors**. The sending test varies in length, in that the examiner may stop you after only a few seconds if he is convinced you know how to send well. The code material consists of plain text, or plain language, and will include some numbers and commonly used punctuation. The punctuation may include the comma, period, question mark and slant bar. Also, there usually are some of the common procedure signals which include: AR, SK, BT and AS.

The written exam covers basic theory, general amateur practice and important regulations regarding amateur operation.

We hope you have enjoyed this style of learning . . . and that you have learned a lot. GOOD LUCK ON YOUR SAMPLE EXAM . . . AND EVEN BETTER LUCK ON THE REAL FCC EXAM! CONGRATULATIONS ON YOUR "STICK-TO-ITIVENESS"!

SAMPLE FCC-TYPE GENERAL CLASS LICENSE EXAMINATION

As in the "sample Novice Test" earlier in the book, this "trial exam" will be multiple-choice. Again, we want you to use the special test sheet to mark your answers.

EXAMPLE

3. Who was buried in Washington's Tomb?
   a. General Grant
   b. General Washington
   c. General Lee
   d. General Nusance
   e. None of the above

You would complete your test sheet as follows:

1. _____
2. _____
3. _____B_____

Etc.

You remember how it works, don't you? Remember—mark the letter that BEST answers the question.

When you are through the test, you can use the Answer Sheet provided at the back of the book to check your answers.

GOOD LUCK! Read **carefully**, and THINK!

SAMPLE FCC-TYPE GENERAL CLASS LICENSE EXAM

1. The maximum input power to the final stage of an amateur transmitter should not exceed:

   a. 5 watts
   b. 10 watts
   c. 100 watts
   d. 1KW
   e. 1000 KW

2. A series resonant circuit is characterized at resonance as having:

   a. Minimum current
   b. Maximum impedance
   c. High resistance
   d. Maximum current
   e. None of the above

3. The main characteristic of an Electrolytic capacitor is:

   a. A high capacitance-to-size ratio
   b. Not polarity conscious
   c. A low opposition to DC current
   d. Economical
   e. None of the above

4. The inductance of two 5 Henry inductors in series is:

   a. 5 Henries
   b. 2.5 Henries
   c. 10 Henries
   d. 25 Henries
   e. None of the above

5. A 1 uf capacitor is connected in series with a 2 uf capacitor. The total capacitance will be:

   a. 0.66 uf
   b. 3 uf
   c. 3/4 uf
   d. 1/2 uf
   e. None of the above

6. The formula for finding the resonant frequency of an LC circuit is:

   a. $f_r = 2 \quad f_L$
   b. $f_r = X_L + X_C$
   c. $f_r = 0.159/\sqrt{LC}$ or $1/2\pi\sqrt{LC}$
   d. $f_r = Z \times Q$
   e. None of the above

7. When $X_L = X_C$ in a parallel LC circuit . . . the circuit:
   a. current will be maximum
   b. impedance will be minimum
   c. phase angle will equal 90 degrees
   d. will not be at resonance
   e. current will be minimum

8. If a series resistive circuit has a 10K and a 20K resistor in series . . . what is its total resistance?

   a. 10K
   b. 20K
   c. 15K
   d. 30K
   e. 6.66K

9. What is the inductive reactance of a 10 Henry inductor at a frequency of 1000 Hz?

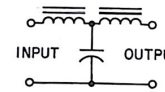
   a. 628 ohms
   b. 6280 ohms
   c. 62.8K
   d. 10K
   e. None of the above

10. Using the same transformer in each case . . . what would be the average DC output of a bridge rectifier (unfiltered) compared to a conventional FW rectifier (unfiltered)?

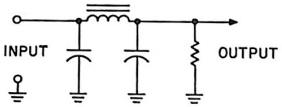
    a. The same output voltage
    b. Twice the output voltage
    c. one half the output voltage
    d. three times the output voltage
    e. None of the above

11. Which of the circuits below represent a "capacitor-input" pi type filter?

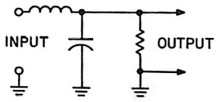
A.



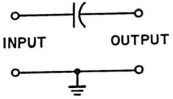
B.



C.



D.



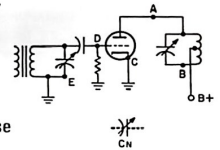
E. None of these.

12. The main elements in a triode tube are:

    a. emitter, base and collector
    b. cathode, control-grid, screen-grid, plate
    c. plate, control-grid, cathode
    d. heater, plate
    e. cathode, grid, screen supressor, plate

13. Between what two points is C_n appropriately connected to obtain the proper schematic for "plate neutralization".

    a. A & B
    b. B & D
    c. A & D
    d. A & E
    e. None of these



14. If the maximum voltage along a transmission line is 4.5 volts, and the minimum is 2 volts . . . what is the SWR of the line?

    a. 2
    b. 4.5
    c. 2.25
    d. 1
    e. None of the above

15. Which of the trapezoidal waveforms shown below represents "overmodulation"

A B C D

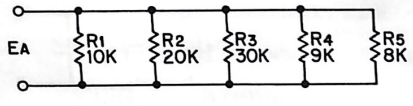
E. None of these

16. *According to Ohm's Law, if the applied voltage to a circuit is doubled, and the resistances throughout the circuit remain the same, what will happen to the circuit current? (CHOOSE THE* **BEST** *ANSWER)*

a. It will increase
b. It will decrease
c. It will remain the same
d. It will double
e. It will halve

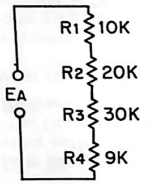
17. In the circuit shown below, which resistor will dissipate the most power?

a. R_1
b. R_2
c. R_3
d. R_4
e. R_5



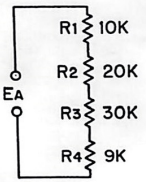
18. In the circuit shown below, which resistor will have the most current through it?

a. R_1
b. R_2
c. R_3
d. All equal
e. None of the above



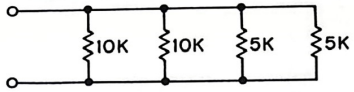
19. In the circuit shown below, which resistor will have the lowest voltage drop?

a. R_1
b. R_2
c. R_3
d. R_5
e. All equal



20. What is the total resistance of the circuit shown below?

a. 2.5K
b. 5K
c. 1.66K
d. 2.75K
e. None of the above



21. What is the capacitive reactance of a 5 mfd. capacitor at a frequency of 1000 Hz.?

a. 159 ohms
b. 0.0000318 ohms
c. 31.8 ohms
d. 31.8 K
e. None of the above

22. If a circuit consists of a 10K resistor in series with a capacitor whose Xc is 10K ohms, the impedance of the circuit will be:

a. 20K
b. 5K
c. Greater than 20K
d. More than 10K, but less than 20K
e. Less than 10K

23. To lessen the possibility of TVI, a radio amateur should:

a. Use a low-pass filter on his transmitter
b. Use a lower antenna
c. Insert a high-pass filter on his transmitter
d. Not transmit on the 80 meter band
e. None of the above

24. The term "skin-effect" refers to:

a. RF energy penetrating the operator's skin
b. Tendency of high frequency current to travel along outside surface of conductors.
c. The effect of the outer protective plastic covering on coaxial cable operation.
d. The ability of radio energy to skin through space.
e. None of the Above

25. What is the fifth harmonic of 50 Hz?

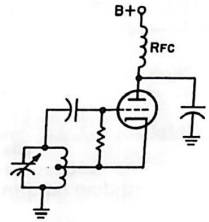
a. 10 Hz
b. 50 Hz
c. 250 Hz
d. 500 Hz
e. 100 Hz

26. The reason a center-tapped filament winding is used on transmitting tube filament transformers is:

a. To divide the voltage
b. To prevent hum modulation
c. To provide two output voltages
d. To divide the load
e. None of the above

27. What type oscillator is shown in the diagram below?

a. Colpitts
b. Pierce
c. Hartley
d. Electron-coupled
e. None of these



28. What type of transmission is an A.M. phone station using?

a. A1
b. A2
c. A3
d. A4
e. A5

29. What is a receiver's I.F. frequency if when the set is tuned to 1200 kHz, the local oscillator is operating at 1655 kHz?

a. 1655 kHz
b. 455 kHz
c. 2855 kHz
d. 1200 kHz
e. 655 kHz

30. What is the wavelength in free space of a 3.0 MHz signal?

a. 1 Meter
b. 10 Meters
c. 100 Meters
d. 1000 Meters
e. None of these

31. What is the power in the sidebands of a 100% single-tone modulated A.M. signal if the carrier power is 200 watts?

a. 200 watts
b. 65 watts
c. 265 watts
d. 100 watts
e. 33.3 watts

32. SWR is caused by:

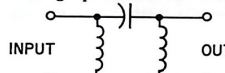
a. Too high an antenna
b. An impedance mismatch
c. Transmitter out of alignment
d. A "matched" load
e. None of the above

33. If a final RF amplifier tube in a transmitter has a maximum plate dissipation rating of 100 watts; could it safely be used if the DC input power were 200 watts and the plate efficiency 60%?

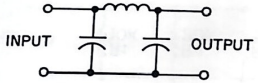
a. Yes
b. No

34. Which circuit below represents a "constant K Pi section high-pass" filter?

A.



B.



35. What is the Beta of a transistor whose base current is 10 microamperes, emitter current is 1 mA, and collector current is 0.97 mA?

a. 1
b. 100
c. 97
d. 10
e. 9.7

36. Which type antenna is noted for having a "low angle of radiation"?

a. The Hertz
b. The Marconi
c. None of these

37. Equalizing resistors are often used across series capacitors, or rectifier diodes to:

a. Equalize the voltage across each element
b. Equalize the current through each element
c. Equalize the power dissipated by the circuit
d. To increase the circuit impedance
e. None of the above

38. How much power is being dissipated by a 10K resistor which has 0.2 amperes passing through it?

a. 20 watts
b. 40 watts
c. 400 watts
d. 4000 watts
e. 200 watts

39. Is it safe to operate a crystal-controlled transmitter within 10 kHz of the 7.0 MHz "bandedge" if the crystal tolerance rating indicates a frequency accuracy of plus or minus 1%?

a. Yes
b. No

40. Is a Zener diode "forward", or "reverse" biased for normal operation?

a. Forward
b. Reverse

41. What frequency can a General Class licensee use for phone operation on the 40 meter band?

a. 7.2-7.3 MHz
b. 7.225 - 7.3 MHz
c. 7.025 - 7.150 MHz
d. 7.150 - 7.225 MHz
e. None of these

42. A class B amplifier conducts:

a. About 50% of the time during each input cycle.
b. about 100% of the time during the input cycle
c. less than 50% of the time of the input cucle
d. 10% of the time during each input cycle
e. None of these

43. Are there countries in the world with which the U.S. does NOT have "3rd party agreements" but yet amateur operators can talk to other amateur operators from that country?

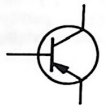
a. Yes
b. No

44. Which of the items listed below can help reduce interference to others on the band?
a. Use maximum power for transmitting
b. Use a directional antenna
c. Use 100% modulation
d. Tune up using your regular antenna
e. None of the above

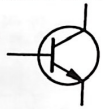
45. To help avoid shock from electrical equipment in your station, you should:
a. Leave power supplies uncovered so you can see them.
b. Only work on equipment with power on, so pilot lights illuminate your work area.
c. Open all "bleeder" resistors
d. Ground metal cabinet and enclosures.
e. None of the above

46. Which symbol below represents an NPN transistor?

A.



B.

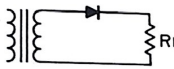


47. Some causes of grid current flow in a Class A amplifier might be:
a. Too much bias and too much input signal
b. Too little bias and too little input signal
c. Too much signal input, and too little bias
d. Bad grid in tube
e. None of the above

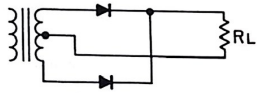
48. One cause of excess plate current in a Class C RF amplifier might be:
a. Too "light" loading of final amplifier
b. Plate tank tuned to resonance
c. Too little plate voltage
d. Too little bias
e. None of the above

49. Which circuit shown below represents the conventional FW rectifier system?

A.



B.



50. What might be done to protect the amateur station equipment from lightning?
a. Use a lower antenna
b. Be sure equipment is properly plugged-in
c. Use an antenna "grounding switch" when station is not in use.
d. Paint the antenna
e. None of the above

"Q" SIGNALS COMMONLY HEARD "ON THE AIR"

QRM = Is my transmission being interfered with? or Your transmission is being interfered with

QRN = Are you troubled by static? or, I am troubled by static

QRT = Shall I stop sending? or, Stop sending

QRZ = Who is calling me? or, You are being called by . . .

QSL = Can you acknowledge receipt? or, I am acknowledging receipt

QSO = Can you communicate with . . . direct or by relay? or, I can communicate with . . . direct (or by relay through . . .)

QSY = Shall I change to transmission on another frequency? or, Change to transmission on another frequency (or on . . . kHz)

QTH = What is your location? or, My location is . . .

THE LETTER AND NUMBER SYSTEM OF REPORTING THE QUALITY OF SIGNALS BEING RECEIVED

The ARRL recommends the following standard system of reporting "signal readability", "signal strength", and "tone" (tone of C.W. transmission)

The three scales used for this system are: 1-5 for readability; 1-9 for strength; and 1-9 for tone.

Here's the famous R-S-T system: (readability-strength-tone)

READABILITY:

1 = Unreadable; 2 = Barely readable; 3 = Readable with considerable difficulty; 4 = Readable with practically no difficulty; and 5 = Perfectly readable.

SIGNAL STRENGTH:

1 = Faint signals, barely perceptible
2 = Very weak signals
3 = Weak signals
4 = Fair signals
5 = Fairly good signals
6 = Good signals
7 = Moderately strong signals
8 = Strong signals
9 = Extremely strong signals

SAMPLE NOVICE EXAM ANSWERS

1. C
2. D
3. C
4. E
5. C
6. B
7. C
8. B
9. A
10. E
11. D
12. B
13. C
14. B
15. A
16. B
17. E
18. D
19. B
20. D
21. E
22. C
23. B
24. B
25. C
26. B
27. B
28. C
29. B
30. B
31. C
32. D
33. C
34. B
35. D

SAMPLE GENERAL EXAM ANSWERS

1. E
2. D
3. A
4. C
5. A
6. C
7. E
8. D
9. C
10. B
11. B
12. C
13. B
14. C
15. C
16. D
17. E
18. D
19. D
20. C
21. C
22. D
23. A
24. B
25. C
26. B
27. C
28. C
29. B
30. C
31. D
32. B
33. A
34. A
35. C
36. B
37. A
38. C
39. B
40. B
41. B
42. A
43. A
44. B
45. D
46. B
47. C
48. D
49. B
50. C

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